Can hype be a force for good?

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Declaration

This thesis is original work. None of the work has been previously submitted for the purpose of obtaining a degree or diploma in any university or other tertiary education institution. To the best of my knowledge, this thesis does not contain material previously published by another person, expect where due reference is made in the text.

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Abstract

Hype takes the form of visions and stories, articulated through optimistic or pessimistic expectations. Visions of desirable futures to work towards, or undesirable futures to work against, help to motivate support for research and gather necessary resources, including funding and political capital. From research proposal through to commercialisation, science hype occurs at all stages of the research process. It is produced by all manner of science and technology actors as they imagine and invent technoscientific futures.

To investigate the role of science hype in this thesis, I construct a conceptual framework that adopts research on sociotechnical imaginaries, anticipatory governance, and notions of convening publics. I use this framework to argue that hype is a communicative device that can spark unexpected engagement with science and technology futures. I test this framework using three cases studies in which hype is used to advance support for science and technology.

In these case studies, hype helps shape the future of scientific research and technology development within the contexts of: human exploration of Mars; quantum-enabled technologies; and grand challenge-driven mandates for research. Hype, in a sense, prototypes those futures by establishing the viability and potential of the topic at hand. Within these case studies, hype is adopted to advance rhetoric concerned with competition, global leadership, and societal benefits. The events documented in these case studies affirm the ideal of science and technology ensuring progress and advancement. However, within the last case study, a different narrative emerges.

This narrative suggests a new role for hype; one which draws on anticipatory governance. It opens the way for discussion on how hype might be repurposed in aid of science and technology that is created with, rather than for, society. In this scenario, the use of hype invites response, agreeable and otherwise, to potential shared futures.

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Preamble

"I think [hype] is extremely dangerous. This is why some sort of national advisory board or some sort of national strategy [for quantum] is important just to contain that and rein it in. It is easy in the early stages where no one's heard about the new field for it to be overhyped because you need to get attention, or you won't get the message out but it's extremely dangerous."

(Interview with *Senior quantum physicist A*, Chapter 4)

What is it about hype that evokes such strong emotion around its use? Researching and writing a thesis on hype in science has been an eye-opening experience. Other researchers have strong opinions about hype. In answer to the question: what is your PhD about? The answer "hype in science" was enough to spark conversations on the presence of sensationalisation in science press releases and media reports. In this thesis, I look at the story of hype. I consider its function on the macro-level for science and technology futures. I outline three separate examples of how hype has worked across years and continents to build specific technoscientific agendas.

The quote above is from one of the interviews I conducted during my second case study, which looked at the hype present in national quantum strategies. The researchers I interviewed generally considered hype to be a necessary evil. It was a way to communicate with politicians and policymakers and a tool to leverage funds. Hype was dangerous and easily utilised by the unscrupulous to unfairly benefit their cause or field. The drawbacks of hype – like those points noted in the quote above – were never far from my mind during this research. However, I contend that it is important to consider whether there are benefits that come through the use of hype. With that in mind, I ask one question: Can hype be a force for good?

Chapter one: An introduction to science hype

Did you hear the story about the lesbian lizards from Mexico? The name of these lizards is, in truth, a misnomer. More accurately referred to as the New Mexican Whiptail, this species has an unusual way of reproducing called parthenogenesis. Parthenogenesis is a mode of reproduction in which the embryos do not require fertilisation. This process has been studied extensively among the New Mexican Whiptail genus which includes fifteen species of lizard that produce exclusively in this manner. In fact, the entire Whiptail population is female. Despite reproducing asexually, the Whiptail still engages in mating behaviour with other females of its species, which has given rise to the nickname 'lesbian lizards'. The theory is that this behaviour stimulates ovulation. Today, research around these lizards is well established but in the late 1970s when Professor David Crews first put forward his theory on their asexual mode of reproduction the issue was controversial. It was also catchy with *Time* magazine using the headline "Leapin' Lesbian Lizards" to describe the study (Collins & Pinch, 1998). Sensationalised and sexy stories like this one are symptomatic of hype in science.

This thesis takes a unique perspective on hype in that it makes no assumption as to whether hype is good or bad. As I will further discuss below and in the remainder of the thesis, this position accepts the inevitably of hype within the current communicative ecosystem of science and technology and asks whether hype might sometimes be viewed as an opportunity, rather than a problem. This perspective draws on the rhetorical history of hype, which is rich and contentious (Claridge, 2014; Ritter, 2010). As a rhetorical trope, hype is used when "expressing the inexpressible" and "stretches and strains facts and language to transcend the 'ordinary' and communicate as yet unimagined possibilities (Ritter, 2010, p. 2). Hype is a common feature in contemporary language that is made visible through perceived overuse or novelty (Claridge, 2014). Within a study of exaggeration in the English language, Claridge contends that every instance of hype is an intentional linguistic act (2019). Hype allows its users to move beyond standard language and communicate alternative possibilities of meaning and being. The use of hype can be complicated when we are asked to explain what the exaggerations of hype mean (Ritter, 2010). Webb defines hype as "a trope that beckons but also warns; it accomplishes an intensification … [that]

brazenly both invites and distances the audience from the height of an apparently unreasonable position" (Webb, 1999, p. 3). In creating this intensification, hype "encourages active reflection on the different ways in which meaning is constructed and communicated" (Ettenhuber, 2008, p. 210). As I argue in this thesis, this active reflection is the feature which means that hype might operate as a force for good.

Hype, or simplified and sensationalised science, is a common topic among researchers and the other science and technology actors who support and commercialise their work. In science communication, hype comes with an array of preconceptions and 'stop the hype' is a familiar catch cry (Rinaldi, 2012). In a sense, hype in science and technology has become something of a 'folk theory', a common idea formed from expectations and through experience that is not always systematically checked (Rip, 2006). The persuasive strength of these folk theories comes from the way they are adopted and generally accepted by a community (Konrad, van Lente, Groves, & Selin, 2017; Swidler, 1986). The predominant (and negative) view on hype in science communication research is that science suffers problems with hype and that the use of 'breakthrough'-like metaphors in science communication causes mainstream reporting of science to fall to cliché. Hype is considered both a distraction – causing one topic to overshadow others – and a problem – where excessive use of hype results in messages losing power and fostering distrust.

In an age where Brexit, fake news, and Trump have become shorthand for a broken media system, hype is seen to push the dissemination of misinformation (Evans, Meslin, Marteau, & Caulfield, 2011). Here, hype creates obstacles that communicators must overcome before they can focus on new topics. Despite the baggage that accompanies hype, the topic is also the subject of questions. In the course of my research , various science and technology actors have asked me: Is hype the only option when communicating with politicians? Who is responsible for hype? When does hype work well? When does it go badly? Does the use of hype diminish other discourses? These questions have formed the backdrop of my thesis while I have investigated examples of hype where promises and expectations have contributed to the shaping of technologies, fields, and policies.

Hype is prolific in science with examples extending from viral social media accounts and 'breakthrough'-themed press releases, to the claims of the celebrity scientist. In science communication, definitions of hype essentially deal with exaggeration. Specifically, these definitions argue that hype exaggerates the benefits of emerging research or technology

while understating the risks (Caulfield & Condit, 2012). The potential for deception through hype allows for a general dismissal of the tactic. This perspective is often assisted by the intuitive assumption that hype can cause a potential loss of trust in science. Trust is essential for "every profession and every institution" (O'Neill, 2002, p. 3) and public trust in science is a strong predictor for attitudes to science and perspectives on controversial science topics (Sturgis & Allum, 2004). Given that trust in science has enabled an unparalleled period of productivity for researchers, it is easy to understand why concern over an apparent crisis of trust has influenced the drive for public understanding of science (Cunningham-Burley, 2006; Rödder, 2014; Whitbeck, 1995). Perhaps because of this, a number of studies in recent years have focused solely on the negative connotations of science hype.

Within science and technology studies (STS) literature, the 'necessary evil' of hype is pragmatically positioned as integral to the research and innovation landscape (Brown, 2003). In a culture where the future is a commodity, where time is money and 'new' is fetishized, success depends on projecting a clear and compelling vision of the future while shortening timeframes for delivery (Brown & Michael, 2003; Geels & Smit, 2000). This focus on the future exacerbates uncertainty for stakeholders as representations of potential futures are simultaneously highly unreliable and powerfully persuasive. When the futures promised by emerging science and technology are distant and highly variable, hype becomes integral to the process of gaining and maintaining financial and social support (Apreda, Bonaccorsi, Fantoni, & Gabelloni, 2014; Jasanoff & Kim, 2009; Latour, 1987). For Brown and Michael (2003), this process demonstrates a need for a more sophisticated appreciation of how social and technical elements work together to marshal support for projected futures.

Buried within studies of hype is a condition that is rarely acknowledged. Hype is – by all appearances – inescapable for science and technology (Nerlich, 2013). This inevitability of hype presents a conundrum for science and technology actors. On one hand, hype is a monster created by exaggeration, inaccuracy, and even deliberate lies. On the other hand, hype is a helpful tactic that works to create publicity and gain support for science and technology. Here, hype is increasingly vital for researchers asked to demonstrate impact and engagement and allows for societal and political priority setting. This context informs the perspective on hype in this thesis where hype is an aspect of the communicative ecosystem

for science and technology, which must be understood if it is to be used as a force for good. In this thesis, I use three case studies to investigate how hype is used in this ecosystem to draw attention through promotional press releases and partnerships with Hollywood, build momentum for change in science policy and research funding, and imagine how science and technology might address the 'big' problems of our time. These case studies support my exploration of the science communication dilemma of hype in reviewing whether hype is just exaggeration and lies or a simple instrument for communication. Through this exploration I develop a third option, which draws on the contemporary call for democratisation of science and technology and more responsible research and innovation.

Thesis rationale: Situating hype

This thesis is situated in science communication and contributes to research on science hype. The question that motivates this thesis is: Can hype be a force for good? This question aims to challenge the standard science communication approach to hype, which is concerned with stopping hype (Rinaldi, 2012), and instead focuses on how futures are designed and decided in science and technology. By challenging existing approaches to science hype, this thesis invites reflection on how hype might contribute to the democratisation of science and technology.

As a process that creates relationships between publics and actors while also making the issues implicit in science and technology visible, communication plays a pivotal role in stimulating "political and societal opinion making" around science and technology (Nerlich & McLeod, 2016). For this thesis, I am interested in communication processes that are inherently persuasive in nature. Gross argues that rhetoric – or, persuasive communication – in science has two distinct roles as a "theory capable of analysing public understanding" and "an activity capable of creating it" (1994, p. 4). In this context, rhetoric is a "public means of coming to a public understanding concerning public issues" (Gross, 1994, p. 5). It makes collective sense of the past and creates and grounds a common future. Similarly to hype, rhetorics ties to persuasion means that critiques of the discipline sometimes contend that "rhetoric [is] somehow different from the 'truth'" (Leach, 2011, p. 5). Such contentions can presuppose that rhetoric is possessed of "pervasive and corrosive powers" (Fuller & Collier, 2004, p. 14). A contrary view on rhetoric's place in society might instead put forward an argument for rhetoric's role in reconfiguring how people relate to the world and each

other (ibid). In this way, persuasive communication plays a vital role in a fully functioning democratic society.

Rhetoric's contribution to the formation of public perceptions of public issues is a key resource for this thesis. It connects with questions raised by science communication scholars Nerlich and McLeod (2016) as they consider the difficulty of locating the 'right' time to engage with publics on controversial science. They ask: who is responsible for raising awareness of controversial science? Which publics should be addressed? What expertise might those publics bring to bear to these discussions? Communicating about controversial science is rife with ethical challenges as the act of communicating "interferes with a media, policy, information and public awareness ecosystem… in ways that are not easy to anticipate" (Nerlich & McLeod, 2016, p. 485).

Sociologist Mike Michael (2012, 2013) extends on these concerns with a provocation that focuses on unanticipated interactions in engagement exercises. Michael asks us to consider the role of disruptive persons who challenge the standard meaning of things. He calls this person 'the idiot'. 'The idiot' helps a communicative event 'open out' to different possibilities and creates an occasion for inventive problem-making. In doing so, there is a fundamental shift from viewing communicative events as problems in need of a solution to an occasion for reframing and engaging with the issue at hand.

'The idiot' invites critique of the default models of science communication: the deficit, one-way model and the engagement, two-way model. The concept highlights how these models restrict the input of citizens who are not science and technology experts. In the deficit model, citizens are employed as an embodiment of values and ethics to add a subjective dimension to the objective business of determining risk or scientific fact (Michael, 2012). In the engagement model, citizens or 'the public' are juxtaposed to science and viewed in terms of relations of trust or cultural identity (Horst & Michael, 2011). In both models, science and society come into contact in a formalised way via the medium of a communicative event. These engagement activities inherently shape the role of citizens and can also restrict modes of interaction. In fact, attempts at engagement and dialogue can entrench pre-existing divides (Kerr, Cunningham-Burley, & Tutton, 2007).

'The idiot' has been used to break with these roles for citizens, make sense of unexpected engagements, and, consequently, articulate a third model for science communication: the emergence model (Horst & Michael, 2011). The emergence model does

not privilege different parties through directing the flow of information during the science communication. In addition, the parties themselves are not pre-identified. Instead, they form through the establishment of communicative relationships. In this emergence model, coming together and exchanging information creates relationships and identities. Communication, here, is a constitutive force and engagement is a performative process that enables relationships and allows publics, science, and technology to become visible (Horst, 2013).

The emergence model speaks to a push for science communication to ensure reflexivity and self-criticism in science (Bandelli, 2015). It also emphasises that a sustained link between science and democracy requires open and critical discussion between science and citizens (Irwin, 2001). In this process, science communication constructs, reviews, critiques, and challenges engagement processes while also raising the question of how to build a meaningful relationship between science and society (Horst, 2007). As Jasanoff (2007) has previously argued in a seminar, "to maintain trust between experts and publics requires us to think of democracy as a performance whose scripts call for contact and critical reflection and oversight."

Who participates in this performance of democracy? Marres (2005) contends that being affected by an issue calls a public into being, particularly when it is the only way of addressing the problems at hand. Within the frame of democratic decision-making enabled by communication, publics must have the ability to co-create and negotiate meaning (Heath, 2014). This involvement is not equivalent to approval or endorsement (Raman, Hobson-West, Lam, & Millar, 2018). Rather, it is an opportunity to open up alterative options and build new understandings of what futures are desired. Along these lines this thesis proposes that hype as a communicative device might offer a way to further the democratisation of science and technology.

Conceptual framework

My conceptual framework for this thesis is strongly informed by the concept of sociotechnical imaginaries in addition to research on anticipatory governance and the notion of convening publics.

When researchers bid for funding, they often look to the future and make promises for the application or translation of their research. These promises may or may not occur

within the timeframe set, if at all (Brown, 2003). Jasanoff and Kim (2009) capture this future-bidding work within their concept of 'sociotechnical imaginaries' where imaginaries "at once describe attainable futures and prescribe futures that states believe ought to be attained" (p. 120). The concept of sociotechnical imaginaries describes how we witness the prototyping of possible futures where initial expectations and promises are set high to begin the agenda-setting process (Geels & Smit, 2000) (Apreda et al., 2014). This hyping of potential futures not only serves to attract interest, funding, and evoke excitement; it can also encourage people to accept emerging technology and new research (Nerlich, Elliott, & Larson, 2009). It also provides a prompt for 'opening up' discussions on science and technology in the making.

The sociotechnical imaginaries concept was originally devised to explore the way science and technology is framed by nation states in terms of social life and social order. Sociotechnical imaginaries have come to refer to "collectively held, institutionally stabilised, and publicly performed visions of desirable futures" as created and promoted by organisations, social movements, corporations, and more (Jasanoff & Kim, 2015, p. 4). Sociotechnical imaginaries also provide a foundation for both analytic and explanatory work in the social sciences. As Jasanoff (2015) notes imaginaries "have power to move minds and actions at a distance; and, as constructs in part of human thought, they remain continually open ended and subject to revision" (p. 323). Imaginaries describe the way expectations for the future can make those futures real (Burri, 2015; Konrad et al., 2017). For the examples of large scale, 'macro' hype considered in this thesis, sociotechnical imaginaries will form a meta-narrative for how science and technology trajectories are created. Standing in contrast to a science communication view of hype as potentially damaging and problematic, the concept will also provide a platform for discussing why fields' trajectories diverge across time and space with some appearing more durable than others.

Science communication and STS research tell us that hype helps craft vivid depictions of apparently inevitable futures. In this thesis, my conceptual framework draws on anticipatory governance research to question the role of hype in science and open up discussion on the innate potential of persuasive communication. Anticipatory governance is an approach that encourages social responsiveness in science and technology research and development. Here, hype could help create and bring together – or, convene – diverse publics. It would do so by using the future as a resource for intentionally producing

expectations and staging interventions in the evolution of science and technology. As Guston (2012) notes, "anticipation of the outcomes of research, engagement with the public over research as it is being done, and the integration of natural and social science" are the essential ingredients of anticipatory governance (p. 12). A framework of anticipatory governance applied to hype suggests that rather than using hype to capture attention and bring people along to a predefined agenda, hype might be used to draw attention to imagined outcomes and the assumptions that inform them. As in the emergence model, this communication adopts hype to catalyse relationships, identities, and discussions.

To explore these notions further, my framework adopts notions from literature on the convening of publics from researchers such as Barnett (2008) and Marres (2005). 'Public', here, refers "not just to a subject of action, and not just to an object of action, but it also refers to a particular medium through which action should be conducted" (Barnett, 2008, p. 3). The public cannot exist until it is spoken for and it chooses to pay attention and respond. Speaking for publics is risky and hazardous as it "only works by risking the chance of misfires and infelicitous outcomes" (Barnett, 2008, p. 23). To frame this, Barnett writes that "*speaking for others* is not a zero-sum game of silencing or exclusion, but an invitation, an opening up of a scene of claims and counter-claims" (ibid, p. 23).

This communication of public issues attempts to create a collective idea of the future. It is done through rhetoric, which is the "only means its citizens had for making common sense of a common past and for creating and coming to terms with a common future" (Gross 1994 p. 5). By drawing on these three concepts, I link hype and communication for democratic decision-making in terms of hype's potential to advance engagement and reflexivity in relation to shared science and technology futures (Leach, Herington, & Raman, 2019). In the following chapters, I propose that hype – like public relations – be reframed as a way of invoking, crafting, and co-designing shared futures.

Case study selection

In this thesis, I look at the story of hype. I consider its function on the macro-level for science and technology futures. I outline three separate examples of how hype worked across years and continents to build specific agendas. The examples of hype used in this thesis are content and context heavy. To understand the power of hype, which is rooted in the power of persuasive language, the researcher must dig deeply into both the content and

context of each case study. Because of this, the individual chapters for each case study use a different source of data and adopt a different method for understanding that data. These case studies: provide a way of understanding how hype plays out in different arenas; point to the differences and similarities of those uses of hype; and demonstrate the central role of hype in future-shaping for science and technology.

Despite the disparities of the case studies identified below, they share a common theme. In each case study, hype is a means of shaping science and technology-centric futures. Within the NASA case study, this future is concerned with human exploration of Mars within the next decade or so. Meanwhile, the quantum case study is concerned with securing nation-level support for research and development in a field which promises to deliver quantum-enabled devices five, ten, twenty years into the future. Finally, the Grand Challenges approach analysed in the final case study presented a justification for ongoing investment in fundamental research. This justification centres on the attainment of future societal, economic, and environmental outcomes.

The first case study in Chapter 3 investigates NASA's Journey to Mars. NASA has been called "a public relations office that has an agency" (Penley, 1997, p. 67), which makes this case study an obvious first stop for a thesis dealing in science hype. This investigation looks to a science agency which has been effectively engaged in public relations and science communication for more than fifty years. NASA's longstanding engagement in public relations means that studies already exist which account for its space advocacy in the past (McCurdy, 2011; Starr, 2008). NASA's seemingly inevitable presence within discussions of space exploration is the legacy of this advocacy. In my thesis, this case study is a more recent reflection on the agency's evolution and engagement with film and media to promote a new Mars-centric campaign. In this case study, I investigate how the film *The Martian* acts as a diegetic prototype for human exploration of Mars and conduct a qualitative conceptual metaphor analysis using software called *Leximancer* on a corpus comprised of press releases, media coverage, and lobbying documents. Here, hype works to attract public attention to NASA's Journey to Mars and reinforces the agency's presence in discussions of human space exploration in the future.

The second case study in Chapter 4 starts from the premise that a second 'quantum revolution' is forthcoming. This quantum revolution promises the development of an array of new technologies and has been the subject of substantial speculation and investment by

nations and corporations. Hype in the context of quantum has been rising while an international cohort of quantum physics researchers have worked to frame the future of their field so as to fit with national agendas. In this case study, I conduct a rhetorical analysis of documents produced in the lead up to and establishment of three national strategies for quantum science and technologies. This rhetorical analysis is supplemented by interviews conducted with 'elite framers', physicists who supported and advised different actors during the creation of the strategies. The revolutionary rhetoric used to frame these technologies is both strategic and performative. As a result of this, features of the case study corresponded with elements of hype as described by STS literature in which expectations shape notions of a new technologies potential and proximity to market. This hype has packaged up a world in which quantum technologies are desirable and useful and will likely continue to influence how and when these technologies are developed and adopted.

The third case study in Chapter 5 examines three examples of grand challenge-inspired programs in the European Union, United States, and Canada. Grand challenges attempt to foreground the societal impact of research. Hype for these challenges is urgent, optimistic, and global in scope. This scope contrasts with the national and transnational settings in which these programs are located. In this case study, I conduct an argument analysis informed by epideictic rhetoric on documents and online sources from the grand challenge programs. These grand challenges are driven by visions of the future, which celebrate the potential of science and technology-driven solutions to societal problems. This opens the way for the use of anticipatory governance to initiate discussions around why and how research is being done and by whom. The case study witnesses various attempts to situate humanity within science and technology and enables a discussion of how hype may help initiate more inventive problem solving and engagement with publics.

The research problem

The problem I address in this thesis is: can hype be a force for good? The aim of this thesis is to explore the nuances of hype, its representations in science communication and in other fields, and to understand the role hype plays in world-shaping for science and technology. As such, my research is also informed by the followed subsidiary questions:

1. How does science communication characterise hype?

2. How can hype be understood as part of the communicative landscape of science and technology?
3. How might hype contribute to the democratisation of science communication?

Evolution of the thesis

Science communication can appear to be a divided field with an impression of a gap between practitioners and researchers (Miller, 2008). As a field, science communication is diverse, made up of actors who write and edit science texts, organise outreach events and tours, train scientists, manage exhibitions, and more (Gascoigne & Metcalfe, 2017). Professionalisation of the field has been marked by different uses of the term 'science communicator' to refer alternately to scientists, communicators, and social science and humanities researchers (Trench, 2017). Despite this perceived divide, a hybrid science communication role is developing (Priest, 2010). I am one such hybrid science communicator with a background in public relations and applied science communication skills in addition to research training. To a significant extent, this thesis has been shaped by my work as a practitioner in science communication with a research centre in quantum physics and quantum technologies, the Australian Research Council Centre of Excellence for Engineered Quantum Systems (EQUS). This role has influenced the direction of my research and the selection of my case studies.

My initial interest in hype was sparked by the distance between public relations practice and science communication work (Bauer & Gregory, 2007). When I submitted my thesis topic proposal four years ago, I imagined a body of research which was significantly different to what I have produced. I imagined research that would look at trust and engagement in the context of science hype. I wanted to know how hype affected ability of different publics to trust in and engage with science and technology. The thesis topic would have been – and continues to be – a perfectly valid area for investigation. However, as I began to read and scope out my approach, I found a research gap that needed to be tackled first.

The shift from my original proposal to this thesis topic means that the research I present in the following chapter extends further a simple interrogation of the function of hype in science communication. The literature I draw on also comes from science and technology studies and public relations research. These two fields allow me to engage in a

deeper investigation of the role of hype in world-making and future-shaping. They form the foundation of a challenge for actors using hype and, more broadly, for science engagement activities. This thesis asks whether the purpose of hype might be changed, to invite broader publics to engage with anticipated outcomes of research in an effort to co-design science and technology futures.

Overview of thesis

For a moment, reflect back to the story of the leapin' lesbian lizards. That instance of science hype was largely a one-off controversy within the biology community which Collins and Pinch (1998) characterised as concluding in an 'honourable draw' with research and debate continuing as to the exact nature and purpose of the Whiptail lizards' pseudo-mating behaviour. These individual tales of hype in science are intriguing as they reveal how research progresses. However, this thesis is concerned with macro level, long-term hype in which actors work to conceive of and promote specific futures through the creating and management of expectations.

Like it or not, hype appears to be an inescapable part of how we talk about science futures (Nerlich, 2013). This means we need a deeper understanding of what hype is and how hype works. Throughout the chapters in this thesis, I will: draw out both the benefits and the drawbacks of using this popularisation tactic; synthesise literature from the fields of science communication and public relations to find out whether science communication has something to learn about persuasive communication; and delve into three examples where hype has been adopted as a tactic for prototyping the future.

This thesis brings together analytic literature from three fields. In addition, each case study makes use of specific literature which lends further weight to the analysis of the data at hand. To deal with this, in the literature review I explore the most significant contributing areas of literature and show how each contributes useful perspectives on the role of hype in science and technology. In each case study, I further expand upon literature as relevant to those examples of hype. Comparisons between the three case studies will be made in the final chapter (Chapter 6).

In *Chapter 2: Literature and methods*, I establish and explore the notion of hype in science. This chapter presents an account of current research, characterised through three models for hype. I consider the different perspectives on hype provided by science

communication, STS, and public relations literature and argue that there is a clear need to accept hype as part of the communicative landscape of science and technology.

In the following three chapters in the thesis, I examine three separate instances of hype. Each of these case studies draw on STS perspectives on the work of visions, expectation, and hope in gaining support and crafting space for technoscientific futures. As such, the approach to future-making within each case study is interrogated individually before being linked back to core focus on hype as a way to further the democratisation of science and technology. Each of the case studies adopts a different conceptual approach for analysis, chosen to fit with the rhetorical texts available and the context of the case studies. These three case studies build a picture of how hype is used to shape the futures of science and technology, specifically for the human exploration of Mars (Chapter 3), quantum-enabled technologies (Chapter 4), and socially relevant research and innovation agendas (Chapter 5).

In *Chapter 3: NASA's Campaign to Mars*, I examine a NASA communications campaign between 2014 and 2016 that centred around human exploration of Mars in the 2030s. With an extensive history of engaging in public relations and popular culture to build support for space exploration, NASA used the opportunity of the film *The Martian* to create a vision of a human presence on Mars. This case study represents a more 'traditional' science communication perspective on hype in science by interrogating the language of press releases, media coverage, and some lobbying documents. I draw on my analysis of these documents to identify four central metaphors on, or representations of, future human exploration of Mars. This chapter demonstrates that seemingly loosely related press releases and media coverage do more than create five minutes of fame and instead are an integral part of an attempt to set a 'humans to Mars' agenda for the United States. Using the example of the film, *The Martian,* I also show how the hype used in this instance enabled a discussion of the risks and rewards of human missions to Mars.

In *Chapter 4: Charting the (second) quantum revolution*, I interrogate the rhetoric contained within policy documents from 2014 through to 2018. These policy documents were sourced from activities surrounding national quantum strategies in the United Kingdom, Canada, and United States of America. This case study is more aligned methodologically with the STS approach to sociotechnical imaginaries and presents a different take on what 'counts' as hype in science. Through an analysis of the key themes of

these national strategies, I contend that hype is part of the messy, long-term processes through which national science and technology-focused identities are created and maintained. My examination of the use of hype here points to the social change that is necessary for technological revolution and how those social factors shape national approaches to achieving leadership in the 'quantum race'. This analysis is accompanied by interviews with individuals who were involved in various national strategies for quantum. The content of these interviews indicates a clear awareness of the role of advocating for research and technology development and speaks to the conscious use of rhetoric (hype) by science and technology actors.

Finally, my third case study in Chapter 5 charts the way for a discussion of hype's role in anticipatory work for science and technology. In *Chapter 5: Grand challenges for research*, I analyse the epideictic arguments used to position science and technology as delivering the solutions to global problems through grand challenges. Taking three examples of grand challenge-based programs, I review the rationale for research agendas that turn societal problems into scientific challenges and considered the evidence for their claims of impact. In this case study, the hype was urgent and yet optimistic, designed to direct research towards defined priorities, including global health, climate change, and sustainability. The hype used in this case study presents a dilemma as it potentially restricts the solutions to socially complex problems to technological fixes. However, it also opens up a discussion around the anticipatory work of hype and the potential of a different role that allows for the co-creation of shared futures.

In *Chapter 6: Conclusion*, I bring together the theory and findings presented in my thesis. I answer the research questions identified above and argue for a new perspective of hype's role in science communication. In this concluding chapter, I also describe the limitations of my thesis and propose future directions for research.

Chapter two: Perspectives on hype

Starting from the rhetorical notion that "hyperbole is always located in a situation, a context, an economy [in order to disrupt that situation or economy]", this thesis explores hype in science and considers what different examples of hype can reveal about the world-shaping work of science and technology actors. In this chapter, I develop my conceptual framework for my thesis while providing an account of how science communication literature frames discussions of hype and identifying other areas of research from which we can draw a richer view of the topic. I use a well-documented case of hype – Pons and Fleischmann's cold fusion – as a proof of concept for my framework. I draw on three distinct areas of research: science communication, science and technology studies (STS), and public relations. Following on from this review of the literature and cold fusion, I use public relations literature to argue for a different perspective on the role and utility of persuasive communication (or, rhetoric) in science. Finally, I address the methods and framework used to analyse my case studies.

The overview of literature provided here serves as an introduction to the remainder of my thesis in which I use this research to investigate other examples of hype that are less well known. The structure of the literature review below also serves as an overview of the methodologies adopted for each case study as I turn to science communication literature (which predominantly influenced the analysis of my first case study in Chapter 3), science and technology studies literature (which influenced the analysis of my second case study in Chapter 4), and anticipatory governance literature (which influenced the analysis of my third case study in Chapter 5). As I outline the research from which I have created my conceptual framework, I demonstrate the value of bringing together disparate areas of research. The common thread between these areas is advocacy for the future. However, their dominant perspectives on the role, form, and place for this advocacy are markedly different. This is also brought together through my conceptual framework as laid out in Chapter 1, specifically in the use of sociotechnical imaginaries within the analysis of each of my case studies.

The case of Pons and Fleischmann's cold fusion

On 23 March 1989, two chemists announced that they had discovered cold fusion through a simple experiment. The potent combination of public interest in the emerging technology, the ambition of their home institution, and the unorthodox method adopted for broadcasting their work, meant that chemists Stanley Pons and Martin Fleischmann became overnight sensations (Collins & Pinch, 1998). Other researchers were eager to pursue cold fusion research and numerous attempts at replicating the study began. This was made difficult as the first announcement of their work was not made through peer-reviewed publication but instead via a press conference. In the ensuing months, positive coverage of their work peaked and doubts around their results and credibility began to surface. Right or wrong, these doubts were powerful and gave enough cause for the *New York Times* to call cold fusion 'dead'. In turn, the American Physical Society pronounced the study a result of the "incompetence and delusion of Pons and Fleischmann" (Browne, 1989, para. 31).

Cold fusion is a case of hype in science, albeit an unsuccessful one given the future presented by Pons and Fleischmann never quite managed to eventuate. Hype is a contentious issue for science. The day-to-day work of scientists, and broader science and technology actors, is informed by their presentations of the future. Yet, making claims for those futures is a dangerous practice. Anticipating future outcomes of research requires an actor to paint a clear picture of their desired future and practice caution by providing a balanced view of the likelihood of realising that future.

A science communication perspective on hype

Despite the rather clinical stereotype of scientists at work in clean rooms and laboratories, imagination is a crucial ingredient for scientific and technological enterprise (te Kulve, Konrad, Alvial Palavicino, & Walhout, 2013; van Lente, 1993). These imaginings are not a matter of science fiction. As Fujimura (2003) notes, future imaginings undertaken by researchers are "distinct from fantasy, especially in the sense that fantasy refers to thoughts disconnected from projects and actions" (p. 192). Indeed, the imaginative work done by science and technology actors helps to organise essential scientific practice as well as the communities these actors operate within. Science and technology actors are diverse and can include researchers, policy makers, and funders. These actors craft visions of the future and identify the expectations that inform those futures, often by making promises or

highlighting concerns to motivate change and drive momentum (Tutton, 2011). Imagination also unites members of a community through shared perceptions of futures that should (or should not) be realised (Jasanoff & Kim, 2015).

Hype is created through a process of science popularisation. In this process, detailed or technical information is rendered into a form suitable for wider audiences that extend beyond the immediate research team. This rendering, or accommodation, of information forms part the boundary work that distinguishes 'pure' scientific knowledge from popularised, hyped science.

Gregory and Miller characterise science popularisation as an effort to persuade (1998). Similarly, Lievrouw positions popularisation as a process that allows researchers and institutions to gain social currency and gather resources in support of their work (1990). Research on popularised science tends to focus on the task of modifying scientific research for different audiences (Fahnestock, 1986, 2004; Hilgartner, 1990; Lievrouw, 1990). Popularised science plays a significant role in informal learning about science, both for non-specialist audiences and scientists learning about different fields (Falk & Needham, 2013). It performs an essential purpose in communicating research to students and funding agencies and enabling collaboration between scientific fields. It also eventually feeds back into the research process (Hilgartner, 1990). Done well, popularisation shapes desirable social and political action (Falk & Needham, 2013; Nerlich et al., 2009) and, so, there is a strong drive to produce popular science and to be popular for researchers and research organisations.

Hilgartner (1990) describes a two-stage model for science popularisation. In this model, a boundary is maintained – usually by scientists and experts – between 'pure' scientific knowledge and distilled popular science. By preserving this distinction, an authority through epistemic 'purity' is maintained for the expert. However, this clear-cut boundary is near impossible to maintain with no true binary of knowledge and popularised knowledge. Instead, a spectrum of audiences, contexts, content types, and roles (for instance, scientists acting as entrepreneurs and scientists acting as policy advisors) affects the interpretation of scientific knowledge (Hilgartner, 1990). In this context, even a conference presentation is considered science popularisation as the research is interpreted and relayed to audiences beyond the immediate researcher or research team.

Popularisation is a dynamic term because it describes wide-ranging methods of communication to diverse audiences. This adaptability means that popularisation has an

agenda setting function (Edy & Meirick, 2006; Scheufele & Tewksbury, 2006; Weaver, 2007). Popular science can highlight a specific area of research or a technology so that an "idea gains currency in the everyday discourse of the general public" (Lievrouw, 1990, p. 9) and enables advocates to secure resources for pursuing the area of research (Gregory & Miller, 1998; Lievrouw, 1990). In doing so, science and technology actors who dabble in popular science are also working frame science and technology issues and set societal and political agendas.

Where a framing study would examine how people think about an issue, an agenda setting study looks to how information is rendered salient accessible for audiences with reference to priming (Weaver, 2007). Framing studies are relatively common in science communication literature with researchers looking to examine how messages are constructed, interpreted, and potentially acted upon (Scheufele & Tewksbury, 2006). Agenda setting is typically measured by examining how media agenda aligns with public agenda while framing is measured by adoption (evaluating whether exposure to media frames shifts public opinion). Weaver (2000) outlines three distinct processes within agenda setting. They are: agenda building, agenda setting, and priming (see figure X). Agenda building looks to the processes that build agendas and the way topics are brought to public attention. Agenda setting examines how the media selects the topics that people should think about by outline a causal relationship between the amount of media coverage and a topic being added to the public agenda. In the final stage, priming looks at whether the topic has been added to the public agenda and subsequent actions or results. As an essentially persuasive process, science popularisation could be portrayed as a method for agenda setting in that it highlights a specific area of research so that "a scientific idea gains currency in the everyday discourse of the general public" and enables advocates to secure resources for pursuing the area of research (Gregory & Miller, 1998; Lievrouw, 1990).

Lievrouw's framework for science communication cycle presents a way of charting how science popularisation occurs. The model deals with how ideas are presented, starting at the beginning of scientific research and meaning making and working through to the popularisation of research among non-specialist publics. Building on the standard popularisation model of progressively simplifying science – defined from the point that communication moves from internal, technical discussion to wider conversations with a variety of audiences – Lievrouw (1990) provides criteria for that move. The three stages of

the model are: conceptualisation, documentation, and popularisation. The first stage, conceptualisation, deals with small groups of researchers and is largely informal as the researcher begins to construct meaning for their research. The second stage, documentation, consists of more formal knowledge sharing among the researchers' immediate discipline, for instance through publishing journal articles and giving conference presentations. The third stage, popularisation, introduces these new concepts to society at large and these concepts, ideally, become part of everyday discourse. The popularisation stage aims to reach people beyond researchers and knowledge brokers (such as journalists) and, so, larger communication structures are involved.

The third stage – popularisation – is rendered distinct from the other two stages through the way core concepts are communicated. Lievrouw argues that in order for popularised science to engage wider audiences, it must somehow fit into the values or beliefs of the larger culture which supports the research. This means researchers must behave not only as discoverers of knowledge, but also as translators and promoters. As in Latour's account of "insider scientists" (1987), this promotion aspect is an important function of science communication and is vital for researchers "because scientists involved in its creation depend on the acceptance of their ideas by colleagues and the general public for continued support" (Lievrouw 1990, p. 8). Drawing on Gamson's earlier work (1988), Lievrouw presents three essential criteria for popularisation. First, the research must be anchored with unfamiliar elements classified into a set of categories and objectified with abstract and unfamiliar elements converted to the concrete and familiar. Second, the issue must become a central element of a narrative with a frame and a storyline. Third, the narrative should be picked up in the broadcasters – or, in the present day, by non-traditional, 'new' media – as a result of its cultural resonance, promotion by sponsors with an interest in its success or failure, and fit with media practice.

An unambiguous example of this practice is prototyping in film. Prototypes work by establishing the viability and potential of emerging technology (Schuman, Trigg, & Blomber, 2002). In an exploration of the persuasive power of science within film, Kirby (2010) adopts this concept and coins the term 'diegetic prototype' to encompass representatives of science and technology in film that work to demonstrate utility, harmlessness, and viability to large audiences.

The rhetorical power of films is partially due to the realism of films coupled with the appearance of scientific authenticity (Hallam & Marshment, 2000). Here 'realism' refers to the plausibility of the film as plot developments and technologies must seem logical to the audience in the context of the film's fictional world. When this is achieved, the cinematic realism contributes to the plausibility of scientific concepts by acting as virtual witnessing technology (Kirby, 2013, p. 34). Space exploration in particular has benefited from a prolonged relationship with the film industry. Over more than eighty years, films have played a vital role in the history of space advocacy and the establishment of space travel technologies. Starting with the 1929 film *Fau im Mond* [*Woman in the Moon*] which was advised by Hermann Oberth, Willy Ley and the Germany Rocket Society) and provided a pivotal visual depiction of the potential of rocket travel. The film impressed key individuals, including Albert Einstein, as well as film critics throughout the world (Kirby, 2013). At the time, the scientific consultant for the film Willy Ley said "A Fritz Lang film on space travel, consequently, meant a means of spreading the idea which could hardly be surpassed in mass appeal and effectiveness" (Ley, 1968, pp. 114-115). The film *2001: A Space Odyssey* also brought space travel to audiences in 1968 with a still influential presentation of the cultural and social potential of space (McCurdy, 2011). These prototypes are deliberately fostered by researchers who advise filmmakers to present technology or research that could exist with the social support and financial investment.

Notably, researchers use prototypes in film to foreshadow dire future problems. In one example, Near-Earth-Objects became topical while two asteroid impact films (*Deep Impact* and *Armageddon*) started production. Science consultants for the films used the opportunity to promote the hypothetical dangers of Near-Earth-Objects to influence wider debate on the issue. This type of work is known as the 'war games effect' (Kirby, 2004). These disaster films become a powerful channel for convincing decision-makers and their publics that the apparent solution - a technology or area of research – should be supported. In the case of the Near-Earth-Object debate, the two films swayed public perceptions and influenced the development of a Near-Earth-Object agency for the United States (Kirby, 2013). These prototypes hype particular futures and, in doing so, create expectations that can help enact those futures. In this context, hype works to persuade people and potentially influences decisions to support (or not) research.

Science communication literature related to hype is often more concerned with the risks associated with using hype. For this reason, researchers like Caulfield and Condit define the concept of 'science hype' in terms of messages about science and technology that "exaggerate the benefits of research and underplay the costs and risks" (2012, p. 209). The development of stem cell research and the subsequent rise of stem cell tourism after years of potentially unwise promises for the future is an example of this style of hype. Petersen, Munsie, Tanner, MacGregor, and Brophy (2017) provide a detailed account of these promises and the aftermath in a discussion that highlights the discourses of technological promise, hope, and expectation used in the stem cell tourism market. These discourses began with stem cell research 'breakthroughs' – as hyped by scientists, media, and the wider community in the 1990s and 2000s – which created optimism among stakeholders who were "grappling with the rising number of generative conditions associated with ageing population" (Petersen et al., 2017, p. 3). The dilemma came when the promises made by scientists foundered within the complexities of clinical trials and the many uncertainties inherent to medical research. As one interviewee noted:

> "by rousing public excitement for the promise of stem cell technologies, stem cell supporters may have inadvertently contributed to the creation of a market for offshore treatment, enabling the very charlatans they now criticise" (Petersen et al., 2017, p. 79).

With these implications of stem cell hype providing a background, the potential drawbacks of hype become clear.

Criticisms of hype focus on this neglect of limitations and risk. This lack of balance is often linked to the potential for a loss of public trust in specific research fields (Caulfield & Condit, 2012). However, the limited literature around this topic shows early signs that public trust may be more forgiving than anticipated (Gauchat, 2011, 2012; Master & Resnik, 2011) and that non-specialist audiences are discerning when it comes to identifying sensationalised science content (Peddie et al., 2009). The question raised here, and in my broader thesis, is whether closing down discussions on hype achieves desired outcomes. Indeed, critiques on the use of science hype have been rife in science communication for more than a decade. This appears to have very little impact on the daily practice of science and technology actors looking to drum up support for their research or focus area. I contend

that a more constructive approach might acknowledge the utility of hype as well as its challenges.

Science hype involves the exaggeration or sensationalisation of 'pure' research. It also appears to be an inevitable element of science and technology actors' work. Hype is part of the process of stimulating vital support for research (Brown, 2003; Brown & Michael, 2003; Nerlich & McLeod, 2016). It is future-centric as scientific research is long term; research grants focus on anticipated outcomes while researchers working in the here and now may not yet be (or ever be) certain of how to reach those goals. Researchers face a constant dilemma in which they must engage stakeholders and gain support and attention in the short term for their research project proposals. They must also continually re-engage them along the research journey. Inevitably, this means that researchers eventually make promises for the future in the present to reach politicians, industry, grant organisations, and other publics and these promises may or may not be realistic (Brown, 2003; Latour, 1987).

Hype seems inevitable in science communication. Tim Radford, a science writer and journalist, calls the very act of selecting one story over another an act of hype.

> "The act of writing about something – to choose one topic from the hundred or so potential topics delivered every day in the scientific press – is to hype it. I have chosen this finding rather than that, or the other, so it must be more important, more compelling, more exciting. I select, therefore I hype" (Radford, 2009, p. 147).

For some researchers in the science communication domain, this tendency towards hype is deeply problematic. Caulfield highlights this in an article on his "growing concern about the potential adverse social implications of stories in the popular press that 'hype' biotechnology" that might just "'poison' public support before true benefits of research emerge" (2005, p. 213). In a similar vein, Sumner et al. (2016) and Vinkers, Tijdink, and Otte (2015) each trace the use of exaggeration in the presentation of scientific research. Sumner focuses on the impact of press releases on health news coverage and argues that exaggeration in news stories is strongly associated with exaggeration in press releases. Meanwhile, Vinkers et al. reviews the abstracts of research articles and finds that scientists increasingly adopt positive words in abstracts. These authors note "scientists may assume that results and their implications have to be exaggerated and overstated in order to get published" (2015, p. 3). Other attempts to locate the source of hype focus on different stages of sharing research and cite press officers (Meyer, 2015) and a lack of science-trained

journalists (Willis, 2015) as the culprits. In another study which compares articles written by journalists and scientists in the Italian newspaper *Corriere della Sera,* Bucchi and Mazzaolini (2007) found that articles written by scientists were more likely to present scientific facts as controversial.

With such widespread use of hype evident in science communication endeavours, it seems likely that the hype is adopted and amplified by multiple parties. Caulfield and Condit's hype pipeline is one possible representation of how this might occur with messaging moving from journal and researcher to press office, to journalist and further afield (2012). Meanwhile, instances of hype appear on a scale which starts with simplified research and extends to pure spin from those who deliberately exaggerate or extend the implications of studies (Caulfield, 2005; Nerlich et al., 2009). Making an additional distinction between types of hype, Nerlich (2013) identifies 'honest hype' (hype which occur through the very nature of the subject) and 'politicised hype' (hype which deliberately sensationalises research, often with the intention of gaining publicity).

Hype helps to create publicity and garner support, which is increasingly vital for researchers who must demonstrate impact and engagement for funding (Bubela et al., 2009; Nerlich, 2012). Hype does not, overall, appear to be accidental. Instead, hype is the result of deliberate framing which simplifies research and provides common points of reference between a topic and key publics (Hellsten & Nerlich, 2008). Despite this, hype is rarely discussed in science communication beyond warnings around its use and emphasis on mitigation (Taylor et al., 2015). Despite a lack of any clear link between hype and trust (Nerlich, 2012), this seems largely due to a reluctance to trivialise research and concern that hype leads to misunderstanding (Carvalho, 2007; Edmond & Mercer, 1999) in addition to a belief that hype damages public trust in science (Caulfield, 2005; Master & Resnik, 2011; Nielsen, Jøregensen, Jantzen, & Christensen, 2007).

For Lievrouw's model, the case of the cold fusion was aided in its initial popularisation success because there was an existing public perception of research in fusion energy, which had been the subject of extensive media coverage. Cold fusion could be anchored and objectified by being presented as clean and cheap in the face of traditional 'hot' fusion, which was considered expensive and risky. Cold fusion was described with concrete terms like 'cold' and used simple equipment instead of traditional fusion research equipment, such as particle accelerators. Cold fusion was easy to package once anchored

and objectified as: a catalogue of metaphors were available (such as, cold versus hot), there was a central organising concept of nuclear energy, and a storyline of conflict between traditional and emerging technology emerged. As a result, cold fusion rapidly became prominent in the media. It resonated with themes of progress and efficiency during a time of cost-cutting on a national scale for the United States. The research team's timing was also ideal, if pre-emptive. The discovery was announced before peer review and publication at the annual meeting of the American Association for the Advancement of Science (AAAS) in Washington DC. This helped bring the topic to national prominence and crafted expectations for its future.

Drawing on science and technology studies: Hype and performative expectations

Science hype inevitably produces expectations – both positive and negative – for technoscientific futures. This section outlines relevant science and technology studies literature in relation to this, specifically focusing on sociology of expectations and sociotechnical imaginaries research.

Expectations are statements about future conditions and developments (Borup, Brown, Konrad, & van Lente, 2006; Brown, 2003). They reference assumptions about how the future should be and how likely this change is (Williams, 2006). Expectations are the product of the futures put forward by science and technology actors in the course of strategic communication and dedicated promotional work. As such, they are enduring features of technoscientific work (Konrad et al., 2017). This strategic, promotional work can be direct in the sense of overt campaigning (for instance, the 2017 Marches for Science) or indirect via materialised assessments of potential emerging technology (for instance, the depiction of Moore's law in computing and the physical sciences as discussed in Schubert, Sydow, and Windeler (2013)). Sociology of expectations research places emphasis on collective expectations and focuses on "statements that are more or less publicly available as part of a social repertoire of smaller or larger communities or an element of particular discourses" (Konrad et al., 2017, p. 466). The focus is on expectations as 'social facts' that emerge through collective, dedicated work by proponents (Durkheim, 1988; Konrad et al 2017).

Expectations are performative (Berti & Levidow, 2014). They are enactments of futures and by performing these futures they can be made real (Borup et al., 2006).

Sociology of expectations literature also highlights the collective nature of expectations. Here, expectations are social facts that circulate in public spaces and are taken up in communities when they align with the social values of their audience (Borup et al., 2006; Durkheim, 1988). While the expectations and visions put forward by individuals can also be powerful, collective expectations – whether hopeful or fearful – can influence technoscientific change (Schyfter & Calvert, 2015). They shape the way society makes sense of advances in science and technology and help mobilise, legitimate, and coordinate concrete activities (Borup et al., 2006; Konrad & Alvial Palavicino, 2017; Konrad et al., 2017; Rip, 2010).

Expectations are hype in the sense that they suppose that something will occur in the future that will bring research promises and expectations into fruition (Schyfter & Calvert, 2015). In this way, they both shape the future and the present; they affect the ability of a science and technology actor to see through their promises by helping them access material support, such as funding, networks, and other resources. Because predicting the future – particularly the future of research which has not yet been done – is risky, the expectations produced by actors need to be sufficiently broad so as to have "interpretive flexibility" (Eames, McDowall, Hodson, & Marvin, 2006, p. 1). This means that advocates for the field must resist the temptation to narrowly define promises or outcomes so that new developments can be more easily incorporated into the overall guiding vision. In this context, actors manage societal expectations for their work, build narratives, and begin cycles of legitimation, expectations, social support, funding, development, and disappointment (Apreda et al., 2014; Birch, Levidow, & Papaioannou, 2012). These cycles undermine normatively linear and deterministic accounts of technological development by demonstrating that complex factors – including agenda building by making purposeful promises and establishing organisational and personal influence – can determine the course of the future.

Hype necessarily involves risk and opportunity where the chance to build anticipation and support for, as an example, stem cell treatment may come at the cost of lost public trust (or increased cynicism and fatigue) if the treatment does not eventuate. Brown contains his discussion of hype within the science and technologies studies concept of 'dynamics of expectations'. Here, hype mobilises the future into the present through enunciating a vision of the future and making almost inevitably exaggerated promises in

order to command interest (Brown, 2003). While this hype is relatively simple to identify in hindsight (in terms of the winners and losers of history, the winners were accurate while the losers were engaging in hype), the ability to isolate hype in the present is murky at best.

These expectations are one aspect of more coherent 'packages' of potential futures, such as sociotechnical imaginaries (Eames et al., 2006; Konrad et al., 2017). Initially sociotechnical imaginaries were defined by Jasanoff and Kim (2009) as "collectively imagined forms of social life and social order reflected in the design and fulfilment of nation-specific scientific and/or technological projects" (p. 190). Now, sociotechnical imaginaries have come to refer to the many ways in which visions for science and technology futures are realised in social life. With a broader definition as "collectively held, institutionally stabilised, and publicly performed visions of desirable futures"(Jasanoff & Kim, 2015, p. 19), they are no longer restricted to nation-states. Sociotechnical imaginaries can be created and promoted by multiple groups, including corporations, social movements, and professional societies (Jasanoff & Kim, 2015).

These imaginaries provide an alternative view on hype, which contrasts with the science communication tendency to view hype as a risk and a problem. Sociotechnical imaginaries help us explore the way futures become powerful vehicles that drive stories of progress, policy agendas, and emerging discourses (ibid). The imaginaries are the site of "world making and nation building" (Jasanoff & Kim, 2015, p. 234) where the actors that propagate imaginaries make promises and advocate on behalf of their field or technology (Jasanoff, 2007; Jasanoff & Kim, 2009). They work to shape a world that can host their future by creating visions of advancement and progress, while minimising uncertainty.

Sociotechnical imaginaries reflect on the importance of "values, emotions, and affect along with questions of rationality and epistemology" (Tutton, 2018, p. 521). Tutton argues that this is evident in work that emphasises the close relationship of science and imagination, rather than considering these two domains as inherently opposed (2018). Existing work on imaginaries largely looks at how future-focused narratives support some pathways and close others (Konrad et al., 2017). Sociotechnical imaginaries provide insight into how the role of science and technology is positioned in different countries as well as by different organisations and groups (Burri, 2015). The concept addresses questions of why some science and technology trajectories are more durable than others and how those trajectories diverge "across polities and periods" (Jasanoff & Kim, 2015, p. 5). For the

studies of hype outlined in this thesis, sociotechnical imaginaries help to demonstrate how advocates for futures founded in space exploration, quantum technology, and grand challenges make claims to support their agendas and work to create a space for their vision.

Whereas science communication literature tends to focus on the production of hype and its transfer to different media, STS literature is more concerned with the performative nature of hype (expectations and visions). In other words, STS scholars investigate the "performativity of future representations" and show how these representations "shape the way society makes sense of science and technology" while also affecting other actors' strategies, the shaping of the technology itself, and the development of science and technology fields (Konrad et al., 2017, p. 464). In part, this research looks to representations of the future and charts how those representations change over time (Brown & Michael, 2003).

Expectations and visions shift and evolve over time. One way of depicting these changes between optimism and disappointment is the hype-disappointment cycle, which considers patterns of expectations across time. In addition, to understand the role that expectations play in innovation, Brown and Michael suggest looking at expectations over time in order to note significant patterns of "extreme revolutionary potential" and "despairing disappointment" (Brown & Michael, 2003, p. 4). The Gartner Hype Cycle is one industry-focused representation of those fluctuations in excitement and despair (Fenn & Raskino, 2008). This framework looks at hype as an instrument and describes the deliberate use of hype and predicts fluctuations in optimism and pessimism. The model has been used at Gartner since 2004 as a tool for management decisions. From the perspective of Gartner Hype Cycle creators Fenn and Raskino (2008), the hype cycle is largely a product of human nature. They note that "we need to acknowledge that a certain amount of hype is necessary to expose us to novel ideas and inspire our imaginations to dream up new possibilities" (Fenn & Raskino, 2008, p. 28). Fenn and Raskino define hype as blatant and showy promotion and position it as a natural part of the development of new products and solutions. The Gartner Hype Cycle, as a predictive tool, assists in determining what will be carried forward and what will be left behind. The cycle is presented as a graph. The vertical axis is usually labelled 'expectations' or 'visibility' and represents the market assessment of future values of the innovation. This assessment is based on the premise that "the more visible an innovation is – the more 'hyped' it is" (Fenn & Raskino, 2008, p. 12). The

horizontal axis is labelled 'time' and represents time to productivity, or (presumably) steady sales.

The Gartner Hype Cycle consists of five stages: the innovation trigger, the peak of inflated expectations, the trough of disillusionment, the slope of enlightenment, and the plateau of productivity (Gartner, 2015). The innovation trigger is a breakthrough – or an announcement – that generates interest in the media and for stakeholders. The peak of inflated expectations builds after the trigger as, during a surge of positive hype, more actors join in. The trough of disillusionment represents a dip in popular approval as impatience for results replaces the original excitement. The slope of enlightenment begins as hurdles are overcome. Finally, the plateau of productivity represents a period where benefits are demonstrated and accepted. The Gartner Hype Cycle essentially presents an industry-centric perspective on the performance of expectations and relays how well a vision translates in the marketplace. The cycle provides some interesting insights regarding hype – particularly in terms of the treatment of hype as an indicator of how a research topic or technology are perceived in an industry setting. The cycle positions hype as a tool for creating excitement for new research and innovation among diverse audiences and allows some monitoring of how a community receives and responds to the excitement.

Sometimes, disillusionment occurs to such an extent that the innovation or area of research largely drops off the cycle. Cold fusion was one such case. The innovation trigger of the public announcement by Pons and Fleischmann at the AAAS meeting was followed up a surge of positive hype and an eventual peak of expectations as researchers en masse joined efforts to replicate the study. Repeated failures of these attempts led to increasingly negative hype and an eventual disavowing of Pons and Fleischmann by the American Physical Society. This negative coverage and subsequent damage to the researchers' credibility meant that cold fusion never re-emerged from the trough of disillusionment[1].

Looking to anticipatory governance: Forecasting (and debating) outcomes of research

In light of the information provided by the expectation and imaginaries literature – and in addition to the literature on popularisation and science hype – it is apparent that the future is created and performed in the present, usually by advocates of those futures. Hype plays a

[1] It should be noted that there is some debate as to whether their effort was more complicated than they have been given credit for (Beaudette, 2002).

significant role here in crafting vivid, apparently realistic depictions of inevitable futures. This section considers the context of anticipatory governance research and asks how hype might be adopted to play a different role by contributing to anticipatory governance mechanisms (Boyd, Nykvist, Borgstrom, & Stacewicz, 2015; Guston, 2012) by convening diverse publics (Barnett, 2008; Marres, 2005).

Changing science-society relationships have altered expectations of how science and technology contribute to societal priorities (Bijker & d'Andrea, 2009). These changes are linked to a push for increased accountability and transparency on the part of science and technology actors. As such, research governance now extends beyond risk regulation and compliance with ethical guidelines towards encouraging research 'impact', which should create more than economic and industry benefits (Raman & Mohr, 2014). In the face of this collective drive to 'make research social', governments and research organisations (such as the United Kingdom government and European Commission) have introduced several initiatives to promote new forms of engagement between science and technology actors and 'society' or 'the public' (Raman & Mohr, 2014). These initiatives use the future as a resource for "producing expectations in a more intentional mode, staging interventions in the evolution of science and technology" (Konrad et al., 2017, p. 479). They include technology assessment (TA), responsible research and innovation (RRI), and upstream engagement around emerging technologies.

Future visions are founded on others to be avoided. Advocates for these desirable futures engage in anticipatory acts – such as road mapping and foresight activities – to identify what should be avoided (risks) and included (promised benefits) in their claims for their field (te Kulve et al., 2013; Tutton, 2011). This future construction practice is not only a method for producing expectations, it also allows for a changing of the direction and outcomes of science and technology (Burri, 2015; Konrad & Alvial Palavicino, 2017). In other words when a future is brought into the present by expectations – or hype – there is an opportunity to consider the metanarratives that inform the dominant visions of technoscientific progress and to identify alternative trajectories (Jasanoff & Kim, 2015; Rip, 2012; Selin & Boradkar, 2010).

By studying expectations, we can understand their performativity in the sense of how they shape the present and future (Brown & Michael, 2003; Hedgecoe & Martin, 2003). As highlighted in Chapter 1, this potentially allows for increased democratisation of science

and technology by challenging the implicit authority of science and providing a pathway to employ diverse knowledge and experience to inform decision making (Boyd et al., 2015; Fisher, Boenink, Van der Burg, & Woodbury, 2012; Konrad et al., 2017; Rip, 2012, 2018). Engaging a range of publics with the future of new and emerging technologies and science allows for the co-construction of technologies and society (Felt et al., 2007; Horst, 2007; Irwin, 2001). However, diverse knowledges and experiences can only be employed if communities, and the people who represent them, are engaged with the production of technoscientific visions. To truly allow for accountability and responsiveness in this decision-making, public engagement needs to be more than "'capturing people' on to a predefined agenda" (Barnett, 2008; Raman & Mohr, 2014, p. 268). The research agenda itself must be open to being reshaped and science and technology actors must support free, open discussion and debate about the means and ends to which public funding and research should be deployed. An in-depth review of science and technology actors' commitment to a new contract between science and society is beyond the scope of this thesis. However, the findings detailed in these chapters do indicate how hype might be adopted to help spark the publics into being for these engagement activities.

As referenced in Chapter 1, these discussions fall under the umbrella of anticipatory governance. Anticipatory governance presents a way of extending the democratisation of science and technology by challenging taken for granted assumptions, such as the role of scientific authority, and presents pathways for using diverse knowledge, experience, and reflections to inform decision-making. Rather than viewing the future as an object for study and prediction, this practice looks at how the future is mobilised in the present through promises and expectations in policy documents and legislature and positions it as an object for public imagination (Konrad et al., 2017). Anticipatory governance work – the interrogation of expectations and visions shaping futures – is conducted at various stages of the innovation and research cycle. Working proactively with the future, and activating anticipatory practices in the here and now, allows science and technology actors to be reflexive about the way the future is represented and enacted. In turn, this approach helps to unearth the metanarratives that inform dominant visions of technological progress and consider alternative trajectories of change.

The third and final framework reviewed below is anthropologist Victor Turner's model of social dramas. In this model, conflict and crisis manifests in interruptions that, if

unaddressed, come to public attention and create an opportunity for engagement. Media scholars have previously adopted this model to understand the effect of mediatised public crises and the enactment of social and institutional power (Cottle, 2006; Kampf, 2011). Turner argues that significant stages of our social lives are organised through dramatic terms and social routines (Gross, 2005; Turner, 1978). These routines are designed to help us avoid confrontation and conflict. When conflict does occur, it begins with a breach of social routine and rises to a crescendo during a crisis. Turner frames this conflict through four distinct stages with each stage presented as distinct through their function and the rhetoric used. The stages are the breach, the crisis, redressive action, and reintegration. During the breach an individual or group breaks a common norm. In the crisis stage, the issue widens and division appears. Through redressive action the situation is amended, sometimes through legislature, regulation or judicial decision. Finally, reintegration sees the resolution negotiated. This third framework links to the anticipatory governance potential of hype, specifically in terms of how breaks with social norms or routine sparks the opportunity to reconsider assumptions about shared decisions and futures.

In the case of cold fusion, the breach occurred when Pons and Fleischmann prematurely announced their discovery. They acted against standard procedure by holding a press conference before peer review. During the following weeks, a crisis unfolded as efforts to replicate their work were largely unsuccessful. Ultimately, the American Physical Society elected to dismiss their claims. The focus on cold fusion dissipated and Pons and Fleischmann went back to work in France until 1992 when Fleischmann retired. In Turner's framework, each stage is "distinct not only in function but in other ways… [it has] its own rhetoric of talk and action" (Gross, 2005, p. 3). Here, we have the researchers, the media, and the gradual shift of the research community's position. The announcement of cold fusion sparked an initially interested and positive public into being, which changed to cynical and dismissive when their claims could not be substantiated.

Lessons on persuasion from public relations

While this is a thesis in science communication, I have already adopted literature from STS as it offers a richer way of engaging with the performative and normative nature of expectations and visions for the future. As this thesis is also concerned with the connections

between persuasive communication and the democratisation of science communication, I now turn to literature from public relations.

As I argued in the introduction to this thesis, hype as a form of persuasive communication can provide a public means of understanding public issues. It can prompt reconfiguration of how people relate to the issue and other actors. To further expand on the capacity for persuasive communication in this context, I use public relations literature to broaden the science communication conception of hype and rhetoric.

However, before I can draw upon public relations research, it is important to acknowledge that amongst science communication scholars can be critical of the capacity of public relations to contribute to their field. This critical perspective argues that strategic, 'corporate-ised' communication – in particular, public relations – undermines the value and communicative standards of science and science journalism. For instance, Dorothy Nelkin's work *Selling Science* argues that public relations exploits journalism (1995). Meanwhile, Bauer and Gregory's seminal work *From journalism to corporate communication* concludes that a post-war shift in research funding prompted corporate-style communication, which moved science communication from a more journalistic approach (using investigation, education, and enlightenment) to strategic public relations (2007). Implicit in this work is the argument that public relations will promote more promotional and less critical science media coverage. Bauer and Gregory predict that this development will minimise controversy and healthy scepticism as public relations – a myth-making field by nature – focuses not on critically disseminating knowledge, but on creating celebratory, affirming events and announcements. In science communication more broadly, the object of this line of criticism is often the press release which is held up at the epitome of simplification and exaggeration (Sumner et al., 2016).

In response to this critique of public relations, I suggest that public relations and science communication are not a mismatched pair of disciplines. In fact, public relations and science communication share many common features. As public relations scholar Johnston argues, public relations, like science communication, is "part of civil society, involved in organised activism, and more dependent on function and skill than titled PR operators" (2016, p. 2). Both seek to engage and inform their publics. Scholars in both disciplines produce individual case studies of engagement and outreach, chart the evolution of practitioners' roles, and trace the impact of communication strategies (Burns, O'Connor, &

Stocklmayer, 2003; Nisbet & Scheufele, 2009; Solis & Breakenridge, 2009; Treadwell & Treadwell, 2005). Public relations practitioners, particularly those working as communicators for research institutions, can sit side-by-side and share functions. Public relations plays an integral role in the communication of science and technology and yet public relations some researchers seem to view it the field purely through a negative lens of manipulation and private funding (Bauer & Gregory, 2007; Elsner, 2014). I suggest that there is more to consider when it comes to using persuasive communication for science and technology. Here, I question those basic assumptions around public relations and highlight the potential benefits of using public relations research in science communication. This is particularly relevant for a thesis which is essentially concerned with the role and purpose of persuasive communication efforts – or, hype – in the science and technology ecosystem.

As Trench and Bucchi note in relation to health and crisis communication, "science communication [can] benefit more from a clearer articulation and deeper exploration of its relations with its neighbours than from further insistence on its separateness and uniqueness" (2010, p. 4). With this in mind, first, I look to literature from public relations and consider how these sources might inform a different approach to science communication. Second, I highlight one specific contribution that public relations can make to science communication, which also implies a new role for hype in carrying ideas out into the open. Third, I conclude by reflecting on the shared traits of science communication and public relations.

Reframing the role of public relations

Much like science communication, public relations practice and research diverges. A textbook case of public relations – as presented within university coursework – is primarily concerned with the day-to-day tools of the trade. These are continually evolving and may include social media and digital media training, writing, stakeholder engagement, and communication for politics or social change (Demetrious, 2013; Solis & Breakenridge, 2009; Treadwell & Treadwell, 2005). If those skills sound familiar, it is because science communicators also use them and learn about them in some university programs (Burns et al., 2003). The literature of public relations also contains familiar stories: individual case studies, social media campaigns, and debate over best practice (L'Etang, Coombs, & Xifra,

2014). And, much like science communication, it is in the literature where we find reflexive and, in some cases, conflicting accounts on the purpose and the evolution of the field.

One view of the field's history argues that early public relations work began as a reaction to social movements. However, alternate views on public relations history challenge this notion. The term 'public relations' was already in use by press during the eighteenth century and by the 1830s it started to take on the same context as today by referring to building reputations and relationships (Myers, 2014). Public relations has existed in the sense of deliberate communicative work to influence public sentiment in non-corporate sectors "across time" (Lamme & Russell, 2010; Russell & Lamme, 2016, p. 741). In fact, the nominal start date and framing of the field was selected by public relations historian Scott Cutlip who chose to focus on the function of public relations as represented by agencies in the United States (L'Etang, 2008). As a result, "much of PR is based on organisational (usually corporate) developments" (L'Etang, 2008, p. 327). This corporate-centric view of public relations had "ramifications for the practice and education… [and public relations] has had an ongoing reputation problem" (Coombs & Holladay, 2012, p. 350).

Miller (2000) contends that public relations scholars should pay more attention to the public relations of social movements, also known as activism. Indeed, Lamme (2003) argues, before corporate public relations began, public relations was used in the name of "public-sentiment building" work by the Anti-Saloon League of America. These anti-saloon groups were the very activists that corporates began to respond to by co-opting their tactics (Coombs & Holladay, 2012). The activists had communications plans "largely in place long before oft-cited public relations pioneers such as Edward Bernays and John Hill began practicing" (Lamme, 2003, p. 123). Some scholars believe that activists have continued this dynamic of being early adopters in public relations today by pioneering the use of new media, for instance the use of social media channels to threaten reputations and leverage change (Coombs, 2002; Coombs & Holladay, 2007; Demetrious, 2013). Moreover, a study from Russell and Lamme that examined global public relations prior to 1900 found that "corporations and agencies were neither the creators nor even the culmination of the field's development" (2016, p. 742) These scholars argue that the primary drivers of public relations were institutions (non-profit, profit, and government) and individuals.

We could, therefore, propose a different way of framing public relations as not simply the domain of large organisations but also as part of activism, or creating social change (Coombs & Holladay, 2012). As well as diversifying the type of work done by public relations, the public relations of social movements speaks to the interests of science communication scholars and practitioners. Particularly considering what we now know about the flaws of deficit model thinking, or that using science communication as a solution to ignorance does not fix the issues of disengagement or distrust. Instead, communication driven by a democratic imperative of engagement with science and technology needs to be dialogic and should occur 'upstream' where new science and technology is being created (Borschelt, 2008; Nisbet & Scheufele, 2009; Wynne, 2006). Stakeholders must possess a meaningful ability to comment on ownership, regulation, uses, benefits and risks if the exercise is truly participative and not simply another form of deficit model outreach (Nisbet & Scheufele, 2009; Stilgoe & Guston, 2017). In a very similar vein, public relations academic Grunig writes that communicators "must consistently remind themselves and management that they might not be right, and, indeed, that their organisations might be better off if they listen to others" (2000, p. 28). While this recommendation is by no means uniformly adopted and put into practise, it remains important to view public relations – and, I would argue, science communication – activities in relation to theories of social justice and citizenship to "encourage more accountable and empowering communicative practices" (Demetrious, 2013, p. 4).

Along this line of thinking, Heath argues that "we need a paradigm of public relations that features it as being capable of adding value to the full functioning society" (2006, p. 95). This paradigm would acknowledge that all kinds of organisations – including universities and research institutes – engage in and have a need for public relations. The role of this public relations should look to the good of society, rather than the individual or organisation, and contribute to responsiveness and inclusivity (Brown, 2014). Johnston summarises this kind of role in two words: "access and equality" (2016, p. 62) while Moloney defines it as "a correction to the historically observed PR condition of unequal distribution of communicative resources amongst interests in actual liberal democracy" (Moloney, 2006, p. 170). For science communication, this role for public relations might help convene publics and invite the contribution of different perspectives. This could allow

science and technology actors to "learn from disagreement and avoid common communication mistakes that undermine these goals" (Nisbet & Scheufele, 2009, p. 95).

Holtzhausen's (2000) postmodern analysis of the field makes a similar argument when they claim that public relations should be freed from its narrow definition of corporate communication precisely because of the field's ability to contribute to grassroots democracy, activism, and radical politics. This analysis also claims that, in a world defined by continuous change, public relations presents a way of activating and defining that change in addition to providing a voice for communities. By using these grassroot tactics, public relations then provides a way to connect with audiences beyond the elite, science-enthusiast groups typically attracted by science communication campaigns (Scheufele & Brossard, 2008; Tichenor, Donohue, & Olian, 1970).

In this sense, science communication as public relations can contribute more than the merely celebratory, uncritical, and myth-making contributions anticipated by Bauer and Gregory. The public, then, would be more than a consumer; instead they become active citizens able to participate in discussions over developments that affect their lives. Here, the public forum is not a trade show but a real change for participation and dialogue, which includes respectful debate and a chance to learn from disagreement.

Convening communities

Public relations is inherently concerned with change and resistance to change and, as such, is political (Holtzhausen, 2000). In his appraisal of public relations in the political sphere, McNair (2004) outlines the critical positions adopted by UK media scholars who saw public relations as "undermin[ing] the communicative and discursive standards required of a healthy democracy" (2004, p. 327). McNair takes the view that a "less judgemental, more pragmatic" approach to the tools and mechanisms of public relations is necessary given its irrevocable role in political communication (2004, p. 327). Here, I adopt this perspective and take the view that the only truly rational approach for science communication is to regard public relations as of potential value to science and technology actors.

Using this, we can consider two features that Russell and Lamme (2016) present as the best way to identify public relations activity. These scholars write that, first, we should consider the *strategic intent* of practitioners. In other words, public relations activity can be identified by investigating whether "communication tactics are employed with a specific

outcome in mind, and [where] activities are not random, but actively selected based on the results a communicator hopes to achieve" (Russell & Lamme, 2016, p. 744). The second essential feature that characterises public relations work is *human agency.* Here, audiences of persuasive messages must have a choice in how they respond to those messages. This allows us to differentiate between public relations and propaganda. Taylor and Kent (2014) make this distinction by presenting a continuum of persuasion, which starts with propaganda and moves through to dialogue. On this continuum, public relations is closest to dialogue and distant from propaganda, which is highly strategic and allows for little to no human agency (see also L'Etang, 2008). This essential combination of agency and intent draws on the rhetorical heritage of public relations as no communicative act can be truly effective without knowing, appreciating, and respecting what others believe and think, and why they hold those positions (Heath, 2014). As a result, practitioners in the message and meaning business (here, science communicators and public relations practitioners) cannot be narrowly focused on the self-interest and opinions of the group they represent (Priest, Goodwin, & Dahlstrom, 2018). Public relations here is about working to create dialogue (Kent & Taylor, 1998) whilst competing for time and space amongst multiple voices. In this competition, publics have the right and ability to obtain and judge messages and make decisions. Meanwhile, through dialogue, individuals and groups can co-create and negotiate identity, interest, and socially relevant meaning (Heath, 2014; Mead, 1934), which is vital in any context which requires individuals to make a choice (Nichols, 1963).

There is an inescapable link between democratic decision-making and communication. Communication carries ideas "out in the open" and enables participation by people from all walks of life (Barnett, 2008, p. 3). Barnett (2008) contends that "democracy acquires its value not just by embodying the preferences or will of the many, but also by involving free and open discussion and debate" (p. 3). In this sense of democratic publicness, publics are created or convened by claims to either speak on their behalf or act in their interest. These publics come together because they concur, disagree, or otherwise react to such claims. Public relations is part of this process in creating and conveying these claims and, ideally, facilitating responses. With calls for "more active, open and democratic relations" between science and citizens, public engagement for science needs to become much more than consensus building exercise (Irwin, 2008, p. 200). In fact, there is an increasing demand for forums that allows for rethinking of the modes of

governance for science. In addition, science and technology actors need to frame their messages in a way to activate participation from "wider, more diverse and otherwise inattentive publics" (Nisbet & Scheufele, 2009, p. 1770). Public relations' positioning of the importance of agency represents an opportunity for rethinking how these aims might be achieved.

Science communication and public relations

How and when do science communication and public relations meet? Burns et al. (2003) define science communication broadly by including the "use of appropriate skills, media activities, and dialogue" to prompt personal responses to science, such as awareness, interest and enjoyment, opinions, and understanding (p. 1). Indeed, to work in science communication is to be involved with "anything that conveys information about scientific findings or concepts" (Shipman, 2014, p. 1). Rhetoric, in this science communication tradition, has two distinct functions: first, in creating theory for analysing public understanding of science and, second, by shaping the activities which are capable of sparking it (Gross, 1994). Both public relations and science communication seek to reach publics who are, in some sense, linked with the issue at hand. Practitioners in each field work to build relationships, foster dialogue, and facilitate responses from publics. By doing so, through specifically designed communication activities and with key outcomes in mind, they are unquestionably driven by strategic intent. And, in turn, their audiences are possessed with clear agency – the ability to concur or not with the messages at hand. Publics may then come together because they concur, disagree, or otherwise react to claims (Barnett, 2008).

Both science communication and public relations work within what could be termed an 'overcommunicated' society; practitioners in this space already struggle to attract the attention and engagement necessary to enable proper dialogue and interaction from relevant publics. In the context of that struggle, enforcing an unnecessary division between science communication and public relations does a disservice as we ignore the wealth of information possessed by our neighbours.

A method for understanding hype

In the final section of this chapter, I detail the multiple methods used to make sense of hype in science and outline my approach. Each chapter in the thesis contains more detail about the methods used for individual case studies.

Multiple methods research allows the researcher to draw on data from more than one source and to employ more than one type of analysis (Davis, Golicic, & Boerstler, 2011). In this thesis, I adopted a multimethod research approach and used methodologies with complementary strengths to examine the topics at hand (Hesse-Biber & Johnson, 2015). The methods I used are related as they are all textual and discursive in nature. Below I provide an overview of my approach in this thesis – broadly speaking, these encompassed metaphor, rhetoric, and argument analysis – and describe how these methods provided insight into the production of hype.

While my methods of analysis for each case study were different, the overarching framework for all three drew on the concept of the sociotechnical imaginary, anticipatory governance, and the notion of convening publics. In doing so, this thesis adds to the growing body of research into sociotechnical imaginaries and answers a call for contributions to a theoretical framework that brings together:

> "our scientifically and culturally conditioned perceptions of reality, our capacity to create new collectives through technological as well as social means, and the changes in expectations that arise when science and technology interact with individual self-awareness and the sense of being well-ruled" (Jasanoff, 2015, p. 14)

As outlined in my conceptual framework and in the literature, sociotechnical imaginaries are concerned with collectively held, publicly performed visions of desirable futures. The benefit of this concept is that sociotechnical imaginaries are "collective, durable, capable of being performed; yet they are also temporarily situated and culturally particular" (2015, p. 19). The broad definition of the sociotechnical imaginary allows for its application across diverse examples from different science and technology fields and organisations and, for this thesis, enables the application of my conceptual framework across three different instances of hype.

The framework provided by the sociotechnical imaginary motivated my question of whether hype can be a force for good by providing an overview of how advocates craft visions for the future to create a space that supported their work. The sociotechnical

imaginary has four distinct advantages, which allows it to overcome limitations of earlier work on expectations and visions in science and technology (Jasanoff & Kim, 2015). The advantages are that the sociotechnical imaginary: allows for difference or divergence in the presentation of, and response to, new and emerging technology and research across different settings; connects events and imaginaries of the past with how the future is operationalised in the present; emphasises the role of the social as well as the role of science and technology; and stresses the role of individuals as well as the collective.

These factors – and the ability to account for how the past and present influences future visions – were pivotal to answering the core research question of this thesis: can hype be a force for good? In particular, the imaginary concept, when joined with anticipatory governance focus on the imagined outcomes of science and technology, allowed me to build an argument for a more conscious, reflexive use of hype, which in turn might help further the democratisation of science and technology. The advantages of the imaginary also meant that I could analyse case studies that: diverged in terms of national and organisational presentation of and response to technology and research agendas; connected the past with how the future was used in the present; highlighted the significance of social factors in the evolution of science and technology; and emphasised the role of both communities and individuals in determining a path forward for science and technology matters.

In this thesis, I examine cases of hype to examine how hype is produced, received, interpreted, and responded to in the here-and-now. The examples interrogated in the following chapters are recent, with the 'oldest' case study – the grand challenges chapter – addressing events that began in 2009. The hype produced in these examples is unfinished because, contrary to the example of cold fusion, we have yet to see the final outcomes of the research and technology proposed. The sociotechnical imaginaries concept has been a boon for the analysis of this unfinished hype as the framework allows the researcher to account for past and present activities and how they affect imagined futures. However, in taking this approach, my research here stands in contrast to much of the work that has been done on sociotechnical imaginaries in STS where the focus is generally retrospective and considers the impact of visions described in times past.

Methods of interpretative research and analysis are best suited to operationalising the sociotechnical imaginary (Jasanoff & Kim, 2015). Such methods can be applied to

understand the "means by which imaginaries frame and represent alternative futures, link past and future times, enable or restrict action in space, and naturalise ways of thinking about possible worlds" (p. 24). The metaphor analysis used in Chapter 3 to analyse NASA's Journey to Mars looks to the process of issuing framing and agenda setting to understand how actors guide public imagination towards specific views of progress. Meanwhile, the cross-national comparison in Chapter 4 identifies the "content and contours" of sociotechnical imaginaries and shows how certain imaginaries are situated by time and place (Jasanoff & Kim, 2015, p. 24). Finally, the research discourses on grand challenges mined in Chapter 5 reveal how imaginaries can define societal good for research outcomes.

Conceptual metaphor analysis

In the first case study on NASA's Journey to Mars (Chapter 3), I investigate the metaphors contained within press releases, media coverage, and lobbying documents.

Metaphor analysis is a long-standing practice in science communication research. Metaphors have been used to: investigate how public communication between science and publics occur (Leydesdorff & Hellsten, 2005), interrogate implicit and explicit frames in public debates (Hellsten, Dawson, & Leydesdorff, 2012), examine shifts in promotional discourse (Nerlich & Jaspal, 2012), and chart the influence of language on public perception and scientific understanding of a range of topics (Hellsten, Porter, & Nerlich, 2014). In science communication, metaphors can be deliberately adopted to capture the imagination of scientist and their publics. They help popularise issues, frame particular views, and even legitimise certain avenues of research over others (Hellsten et al., 2014). Meanwhile, in media coverage, metaphors are part of a standard route to making issues concrete, engaging, and newsworthy (Hellsten et al., 2012). My methodology has been influenced by these existing studies as well as an example of automated analysis of frames and metaphors (Hellsten et al., 2012), although I adopt a different content analysis program called *Leximancer*. This approach allows me to automate grouping of text – gathered from large bodies of work – into concept lists, isolate consistent metaphors, and identify relationships within the texts.

I examine the metaphors in NASA's campaign to Mars to gauge how NASA has primed expectations and set an agenda for human exploration of Mars. As discussed in Chapter 2, agenda setting is typically measured by examining how a media agenda aligns

with a public agenda. Consequentially, the analysis I conduct in Chapter 3 is concerned with how the campaign to Mars has been built and conveyed to media and wider audience and how this, in turn, has primed public expectations for human exploration of Mars.

The sociotechnical imaginary, here, provides an overarching framework for discussion on the role of language and metaphor where metaphors work as miniature stories and, when reviewed on a whole, provide a vision of a desired future. The imaginary framework also provides context for how space exploration technology – as presented by NASA – plays a "doubly deictic function pointing back at past cultural achievements and ahead to promising and attainable futures" (Jasanoff & Kim, 2015, p. 22).

Rhetorical analysis

In my second case study on the rise of quantum machines (Chapter 4), I interrogate the rhetoric of three national strategies for quantum physics and quantum-enabled technologies from the United Kingdom, Canada, and United States of America. Rhetorical analysis helps provide insight into the complex relationships of stakeholders with publicly funded research (Ploeger, 2009). In one example – a study of the rhetoric used by the United States Department of Energy's national laboratory for high-energy particle physics *Fermilab* – rhetorical analysis demonstrated how researchers and research managers used specific language to maintain an identity for the laboratory. Rhetoric of science researcher Joanna Ploeger found that the rhetoric of the lab was dominated by image and narrative that was rich in idealism and nostalgia. The rhetoric was constitutive and strategic with textual analysis and interviews demonstrating that employees were highly aware of and could account for their own role in the rhetoric of their enterprise. Using a similar approach, I conduct a rhetorical analysis of the documents produced in the lead up to national strategies for quantum science and technologies.

Once again, sociotechnical imaginaries provide a uniting, overarching framework for this analysis. Building on Jasanoff and Kim's contention that the imaginary begins in the visions of individuals and small groups and consequently develop into an imaginary by gaining traction via coalition building, this analysis looks to the rhetoric within each document to determine whether coalition building was taking place. The sociotechnical imaginary also provides a way for considering how national identities filter through national strategies and, on the flipside, how visions of technological innovation can speak to national

identities in order improve their persuasiveness. Taking this approach in the quantum case study allows me to consider the explicit and implicit hype of the science and technology actors involved and explore the perspectives of individual physicists. To gain a fuller account of the evolution of these – and related – quantum strategies, I interview individual physicists who had been involved with one or more national strategies (not just the three considered here) in the last five years. The interviews provide points of clarity on ambiguous terms and allow for richer discussion of the information collected.

Epideictic rhetoric and argument analysis

In the third and final case study on grand challenges for research (Chapter 5), I review the promissory arguments contained within three grand challenge programs. The three programs are: the European Commission's *Horizon 2020* research and innovation program, the Canada's national global health program *Grand Challenge Canada*, and the *University of California, Los Angeles' Grand Challenges* program. The analysis for this chapter is concerned with how science and technology was positioned in terms of solving societally complex problems. By interrogating the claims made by each program and the evidence supplied for those claims, I trace the trajectory of 'grand challenge' hype and map the establishment and evolution of each program using an approach informed by epideictic rhetoric.

In the study of rhetoric in science, epideictic rhetoric is perhaps the least well characterised genre of rhetoric (Casper, 2007). Seminal works in the field include Fahnestock (1986) and Gross's (1990) inspection of popular science and Sullivan's (1991) identification of five functions of epideictic rhetoric in science writing. Meanwhile, Condit (2018) and Casper (2007) have each examined epideictic scientific discourse in Nobel prize lectures. Research into epideictic rhetoric in science and more broadly is 'Janus-faced' as it must simultaneously account for past event and future implications to generate insight. Existing rhetoric of science studies of the epideictic have chiefly covered the transition of information from forensic rhetoric (i.e. journal articles) to the epideictic (i.e. popular science articles). In contrast, the analysis I conduct in Chapter 5 is concerned with epideictic rhetoric in the form of research agendas and not information in more forensic forms (i.e. research projects and reports).

The examples of hype in this case study contrast sharply with the previous two case studies. The hype is not specific to a single field of research and instead is concerned with the creation of 'better' futures for society in general. The programs themselves are shaped by anticipatory acts that determine what futures are desirable and marry those futures with notions of progress as determined by scientific and technology. Sociotechnical imaginaries' close relationship with the master narrative is useful here as the framework provides a rationale for program evolution as well as the commitment of a society to performing the imagined steps to the desirable future ahead (2015, p. 20). Similar studies in this space investigate representations of future(s) in documents and speech (Felt, Igelsboeck, Schikowitz, & Voelker, 2016). They have also traced expectations and imaginaries at work by considering the strategic practices adopted by science and technology actors. The incorporation of anticipatory governance in this case study enables an investigation of how hype might help science and technology actors commence more inventive engagement and problem solving with wider publics.

Conclusion: Hype in public

In this chapter, I have outlined the current view on hype from science communication and shown how STS and anticipatory governance add to this view, to make it richer and more nuanced when it comes to understanding the research and innovation journey. I demonstrated this by reviewing the events of Pons and Fleischmann's cold fusion through three models from science popularisation and science communication, industry modelling based on expectations, and a model for social dramas. Each of these models provide different insights into the case of cold fusion. Lievrouw's model articulates how the topic achieved its initial popular success. The Gartner Hype Cycle isolates the moment that expectations peaked without corresponding delivery. Meanwhile, Turner's social dramas dictates how the events came to a close. The analysis of the events of cold fusion through these models indicates how the science communication perspective on hype can be extended by accessing research from other fields.

In a similar sense, I also made a case for a reconfiguration of how science communication approaches persuasive communication through the example of public relations research. I have argued that persuasive communication plays a vital role in the context of bringing ideas and concepts into the open for response by various publics. Within

the remainder of my thesis, I will continue this argument by exploring how hype is currently used to further science and technologies agendas. I will outline a case for a conscious use of hype to invite response and reaction from key publics in the course of co-designing technoscientific futures. In doing so, I highlight the need to recognise the agency of communities who can support and resist proposed futures and influence the outcomes of science and technology work.

Chapter three: A giant leap - NASA's campaign to Mars

> *"I put [movies] in the short-term buzz category. But at this point it's really all we have. Mars is so long of a term project and the set of reasons for going are individual and amorphous, it's hard to keep a constant public drumbeat of support for it."*
> *Former NASA Deputy Administrator Lori Garver (Bachman, 2015, para. 10)*

> *"Works of imagination helped to create an image of [space exploration] … these works of imagination helped the public visualise a future in which space travel could take place and helped motivate support for pursuit of the dream."*
> *(McCurdy, 2011, p. 311)*

A feature of hype observed by Claridge (2014) in their study of the rhetorical trope is 'intentionality', or the deliberate use of hyperbole to attract attention and transport the attitude of the speaker to a situation. In this chapter, I investigate the deliberate use of hype by NASA to set science and technology agendas. Specifically, the use of hype to convey NASA's perspective on future human exploration of Mars. I outline the history of NASA and reflect on the impact of this legacy within the agency's contemporary communications campaigns, which blend together tactics from public relations and science communication. I make note of the space agency's longstanding relationship with Hollywood and its use of film to convey specific images of future space exploration. Then, taking *The Martian* as an example of the Journey to Mars campaign, I explore how NASA used a film to promote their agenda, specifically examining how the film became a prototype for the Journey to Mars. In discussing the role of the film (*The Martian*) in setting expectations for a human presence on Mars, I also establish the timeframe for a metaphor analysis of the NASA Journey to Mars campaign. In the third and final part of this case study, I conduct this analysis using media releases and news coverage from the years surrounding the film (2014-2016) to understand how advocates attempted to set an agenda for human exploration of Mars.

The case study detailed here represents a more traditional science communication perspective on hype. Here, I interrogate the language used in press releases, media coverage, and lobbying documents to identify the metaphors that construct NASA's

campaign to Mars. In doing so, I respond to a call in an article by Hellsten et al. (2014) for more research into the construction of futures through tools like metaphors. The metaphors analysed in this case study were adopted to capture public imagination around a human presence on Mars and to drive home the essential role that NASA plays in achieving this goal. These metaphors present an imaginary in which NASA's past achievements and cultural presence reinforce the attainability of the organisation's desired future.

In the 2015 film *The Martian*, the third human mission to Mars is forced to evacuate. Astronaut Mark Watney is left behind. Initially presumed dead, Watney must survive long enough for NASA to find a way to bring him home (Ridley, 2015). NASA is no stranger to Hollywood with the agency regularly providing support to documentaries and films each year. Yet, it appears *The Martian* is different. Perhaps as a result of strategy or through fortunate alignment with the agency's plans, NASA's collaboration with Director Ridley Scott and the rest of *The Martian* team has been called 'more intense' than collaboration on other films (Lidz, 2015). The agency consulted on the film from the first production meeting; this consultation included answering 'hundreds' of questions from the film production team, organising tours of the Johnson Space Centre for the production designer, a screening of *The Martian* on the International Space Station, and launching the front page of the screenplay into space.

Advocates for human space exploration must create a persuasive campaign to allay scepticism and drum up political and financial support (McCurdy, 2011). One notable and recent example of space advocacy is SpaceX CEO Elon Musk's call for recruits for a one-way mission to Mars – a mission likely to have a high fatality rate (Sundermier, 2016). Musk's messaging, which in this instance relies on the draw of adventure and a Star Trek-esque view of colonisation beyond Earth, inevitably hypes the current capabilities of SpaceX and the organisation's focus on Mars. In terms of NASA's own publicly-funded journey to Mars, astronaut Terry Virts and Mark Kelly told the National Press Club that "[getting to Mars] is more a question of political science than rocket science" and it "cannot happen without public support" ("NPC Breakfast with NASA Astronauts Mark Kelly and Terry Virts," 2015). The flipside of building popular support by projecting extraordinary futures, such as people living on Mars, is the need to balance aspirational goals with feasibility (Brown, 2003). This challenge is a common criticism of 'science hype' where the exaggeration of research

benefits comes at the cost of providing information on the risks of science, which can lead to inflated expectations and, perhaps, to loss of trust (Caulfield & Condit, 2012).

Space science communication and advocacy

Astronauts turned social media 'superstars' and appearances at ComicCon are among the many tactics that the National Aeronautics and Space Administration (NASA) uses to connect with popular culture and evoke an imaginary based on the inevitability of a human presence in space. Given the cost of NASA missions and its reliance on public funding, communication tactics such as these are used routinely by the agency to justify continued public investment. Starting with the assumption that science and technology developments are jointly imagined with social orders (Jasanoff & Kim, 2015), this chapter examines how NASA constructed an agenda for a journey to Mars between 2014 and 2016. Public relations researcher Scott Cutlip asserts that public relations has "played a far more important role than the public believes" in American history (1994, p. x). Within this context, NASA has effectively been engaged in a public relations campaign for more than half a century (Starr, 2008). From modest beginnings as the National Advisory Committee for Aeronautics (NACA) to its present form, the agency has attracted and directed both national and international attention towards specific public relations campaigns that aimed to cultivate a space for the agency's continued role in space exploration.

The imaginaries that have shaped NACA/NASA history have shifted over space and time to continually command national and international attention as well as legitimise its continued existence. In the early days of NACA, then executive secretary (and informal public information officer) John Victory emphasised that NACA's 'product' was research information and its efforts to distribute this information consumed a significant part of its public relations program (Starr, 2008). As this program evolved in NASA, Joe Stein of the Office of Public Information said that the NASA public information program should "seek to explain the science to everyone… there is a huge task here… we are fortunate, at least, in having an avidly interested audience – 'space' is the magical word of the day" (Stein in Starr 2008, p. 233).

The space race was the product of successful advocacy and timing with both NACA and NASA portraying their work as "imbued with democratic 'American' meanings and has harbingers of seemingly infinite technology, social, and political progress" (Starr, 2008, p. 4).

Advocates during the space race used these narratives to effectively engage American’s sense of patriotism as well as the nation’s notions of westward expansion and frontier mythology (McCurdy, 2011; Starr, 2008). In McCurdy's analysis, these narratives played an essential role by spreading the idea of space as an inevitable place to explore and secure during the late 1940s (McCurdy, 2011). By the Cold War, and the successful launch of *Sputnik 1* and *Sputnik 2* by the Soviet Union, Americans were primed for the next step. During the Cold War the "imaginations of everyday Americans were deeply engaged... [as] were their fears... [and] some of the first articles published about space during the early days of the Cold War defined it primarily as the location of humanity's next battleground" (Scott & Jurek, 2014, p. 2).

As NASA public relations narratives gained traction within both NASA’s internal culture and externally in public culture, the themes of America first globalism, American national identity and American technological ingenuity became evident, particularly in President Kennedy’s speeches (Starr, 2008, p. 271). These themes encouraged the public to support an imaginary composed of elements which invoked America’s frontier mythology, ‘can-do’ attitude, and elements of science fiction. In her wide-ranging review of NACA and NASA public relations during the Cold War, Starr concluded that one measure of success for early NASA Public Affairs was the extent to which they “popularised the notion of manned spaceflight program as opposed to robotic space exploration or a central focus on the development of astronomy” (2008, p. 312).

In September 1969, rocket engineer and advocate for human space exploration Wernher von Braun said “without public relations and good presentations of these programs to the public, we would have been unable to do it” (Scott & Jurek, 2014, p. ix). Yet during December 1972, as the final voyage of the Apollo project was being completed, journalist David Brinkley on NBC "[praised] Project Apollo for a job well done... [and] questioned why NASA wasn't being shut down and the money spent on something else"(Scott & Jurek, 2014, p. 111). He said, "The American people might wonder if all these billions and all this science, engineering and work might not produce something more useful." These critiques of the Apollo project and space race are expanded upon in Gil Scott-Heron’s 1970 song “Whitey on the Moon” which juxtaposed the moon landing with racial inequality in the United States. Just as Nelson highlights in his seminal work “The Moon and the Ghetto”, technological process in some industries has been much greater than in others.

For example, humankind was able to land on the moon while making little progress in addressing various societal inequities (Nelson, 1977, 2011). These competing pressures have led NASA to find new rationales for space exploration and new sources of public support (Hersch, 2012). In the late 1970s and beyond, this meant space agency turned its attention towards science fiction by supporting the creation of, and aligning its public image with, popular culture, such as *Star Trek* (Penley, 1997).

NASA remains in a precarious position with a constant need to re-engage with its various stakeholders. This has influenced the way the agency chooses to promote its agendas. In 2004, a market study for Space Exploration by Dittmar Associates concluded that (*emphasis* added):

> "Although support and interest remain strong, respondents also expressed discomfort with NASA that, surprisingly, seems to stem less from the challenges the agency has faced in its recent history and more from the perception that although the public supports the space program, the space program is *disengaged* from and *uncaring* about the public. The desire for a *responsive* NASA – one that goes out of its way to involve interested citizenry in real and meaningful ways beyond traditional 'outreach and education' - emerged repeatedly in responses to questions asking about relevance of the space program to their everyday lives" (Dittmar, 2008, p. 3).

The study found that levels of awareness regarding NASA's plans to complete the International Space Station, send humans back to the Moon, and eventually send humans to Mars had decreased between surveys conducted in 2004, 2006 and 2008. In the same period, perceptions of NASA's lack of relevance to respondents' everyday lives and lives of their family and friends remained high with 45 percent (2004 survey), nearly 50 percent (2006 survey), and 30 percent (2008 survey) of respondents considering NASA to be irrelevant or very irrelevant. In answer to how to improve this, respondents voiced a strong desire for a responsive NASA. In answer to the question "What would get you interested and excited by NASA?" answers included: "if I could go [to space]", participation in the mission, and the ability to see what robots and astronauts are seeing in real time (Dittmar, 2008, p. 10). Subsequent recommendations by Dittmar (2008) included the reimagination of missions with 'additional capabilities', such as recruiting public collaborators and the development of multiplayer simulations of space exploration.

In a more recent investigation of how the space race affected communications depicting space exploration, Cokley and Angus (2014) found that emphasis on robotic missions decreased public awareness of space travel and exploration as an endeavour involving humans. Their study indicates that tactics to increase public and political support for organisations involved in space exploration should ideally include reference to human spaceflight. Cokley and Angus investigate the premise that the space race was, and continues to be, a significant driver for space exploration. They cite a key statement for the United States-based Universities Space Research Association (USRA), an organisation established in 1969 during the golden age of space exploration by ex-NASA Administrator James Webb and National Academy of Sciences President Frederick Seitz. The statement explains that they created the USRA to "satisfy not only the ongoing need for innovation in space, but also the need to involve society more broadly so the benefits of space activities would be realized" (Cokley & Angus, 2014, para. 10). This statement "drew a straight line between the space race and the public 'involvement' in space science" (ibid, para. 14). The wording implies not just a desire for public acceptance of or enthusiasm for space exploration, but a model of co-production of an outcome (human spaceflight) that is ultimately done in the name of public good.

Advocacy group *Explore Mars* appears to agree that public support for human exploration of Mars is essential for the realisation of the mission. The organisation's yearly report includes chapters on both the public perception of the humans to Mars campaign and the reception of the campaign in US policy. A 2017 annual report issued by *Explore Mars* identifies NASA and the media as primary influencers in this space and mandates that better relationships be established with national and international press (ExploreMars, 2017). Calls to action for *Explore Mars* collaborators include better storytelling around the journey to Mars and for stronger relationships with Hollywood.

These examples of how NASA has built and re-built its public image illustrate how science and technology actors craft imaginaries to support their agendas. In the case of NASA, the space agency and other actors – such as the advocacy group *Explore Mars* and creators of popular culture – create and promote specific views of desirable futures. In doing so, they make promises and shape expectations for a human presence in space.

Creating an imaginary: NASA goes to Mars

Expectations and promises play a crucial role in creating momentum for developments in science and technology (Brown, 2003). In the case of human exploration of Mars, NASA and its industry partners are attempting to set a 'humans to Mars' agenda for the United States. This chapter explores whether we are witnessing the results of deliberate agenda building in accordance with Hellsten and Nerlich's statement that:

> "Sudden and parallel increases in communications in various discourses (e.g. medical journals, newspapers and discussion groups) point toward connected fluctuations in public debates and possibly to a purposeful use of public hypes to advance scientific research in a specific field" (2008, p. 10).

The analysis conducted for this case study is concerned with how NASA has primed expectations and set an agenda for human exploration of Mars. Here, I examine the context of the campaign and the way the human to Mars topic was added to the public agenda. As an essentially persuasive process, science popularisation can act as a method for agenda setting in that it highlights a specific area of research so that "a scientific idea gains currency in the everyday discourse of the general public" and enables advocates to secure resources for pursuing the area of research (Gregory & Miller, 1998; Lievrouw, 1990, p. 9).

This is hardly the first time that NASA has engaged in strategic communication work with the aim of promoting a new role or exciting mandate for the agency. In *NASA/Trek,* Penley examines the various meanings of 'NASA' in the context of popular science and the space agency's ongoing battle to increase public interest in a program that Bell describes as "uncommonly zeitgeisty for a large sci-tech organization" (Bell, 2005, p. 86). Penley contends that the acronym 'NASA' came to serve as shorthand for individual ingenuity and collective 'can-do' and suggests that NASA has taken a Hollywood 'blockbuster' approach to sustain these meanings. In one example of this approach, the NASA-supported film *Apollo 13* recreated an era where NASA "appeared faultless and even heroic, even though its usefulness as one of the main ideological weapons in the Cold War was rapidly ebbing" (Penley, 1997, p. 13). In the same period, NASA made what Penley describes as a 'hail-Mary pass' in announcing that they had found proof of life on Mars. While NASA Chief Daniel Goldin attempted to use this announcement to revive the agency's mission to Mars, critics worried that NASA was releasing hyperbolic conclusions (Flam, 1993; Penley, 1997).

NASA has consistently sought to reinvent itself and align its messages with the concerns of its publics. A particularly poignant example, and Penley's central thesis, is NASA's relationship to *Star Trek,* which "is interwoven with NASA in dense and complex ways" (Bell, 2005, p. 86). This began in the 1970s when NASA changed the name of its first shuttle from *Constitution* to *Enterprise* and has continued since[2]. NASA has a longstanding relationship to popular culture and the 2015 film *The Martian* is the latest instalment of this relationship. The film draws on ideals of ingenuity and 'can-do' attitude to depict a world where the space agency can not only reach Mars, but rescue an astronaut stranded on it. Watney, stranded on Mars with insufficient food and no way to leave, must find a way to survive in an inhospitable environment with his best chance of rescue years away. What character could better encapsulate Penley's reference to 'individual ingenuity' than a man who mixes the out-of-this-world exploration of Neil Armstrong with the adaptability of MacGyver?

Penley describes NASA's relationship to popular science as "a collectively elaborated story that weaves together science and science fiction to help write, think and launch us into space" (1997, p. 9). This description indicates that a close relationship between the agency's missions and its messaging may make it difficult to extract the 'core' of NASA from the narrative that supports its mission. The space agency has adopted a canny approach to public relations to lever a significant social media following, powerful spokespeople, and science fiction films. One instance noted by journalists in the lead up to the release of *The Martian* was the announcement of water on Mars, which helped fuel interest in the film.

NASA's support of the film was an opportunity demonstrate the viability of a human presence on Mars and the sheer ordinariness of the astronauts' activities there. *The Martian* enabled a discussion of the risks and rewards of human missions to Mars (Dave, 2015). In terms of timing, the film was ideal with indications that public appetite for human exploration of Mars increased. In 2013, *Explore Mars* commissioned a survey which indicates that 75 percent of Americans support "increase[ing] NASA's percentage of the federal budget to one percent to fund a mission to Mars" (Explore Mars Inc, 2013, p. 2). This is a substantial change from Gallup survey results in 2005 which indicates that while Americans were generally supportive of NASA, they were less likely to support a mission to

[2] Penley's book *NASATrek* provides a detailed account of NASA's relationship with popular culture.

Mars with 58 percent of respondents saying they "opposed setting aside the money for an attempted Mars landing" while 40 percent were in favour (Gallup, 2005, para. 6).

In an interview with *Wired*, author of *The Martian* book Andy Weir said that NASA considers the film "as an opportunity to re-engage the public with space travel" (Zhang, 2015, para. 7) and the *Washington Post* said that "Andy Weir and his book *The Martian* may have saved NASA and the entire space program" (Achenbach, 2015, para. 1). While these statements may themselves be hyped, it does appear that supporting *The Martian* was a strategic move by the space agency. Support for the film may also have assisted NASA in fulfilling a goal from its Human Exploration and Operations Mission Directorate communications strategy for 2014-2015. The goal "[to] enhance public and Congressional recognition of the value of human space exploration and understanding of the capabilities-driven approach in our pursuit of sending humans to Mars" is indicative of NASA's #JourneytoMars campaign (Taylor, 2015, p. 8). Specific campaign tactics in support of this goal included assistance during film production as well as news releases, social media and their website (Taylor, 2015).

Sociotechnical imaginaries provide more or less coherent packages of potential futures (Konrad et al., 2017). In the case of NASA's journey to Mars, the imaginary at hand has driven stories of progress in the field of human space exploration. These stories have been conveyed to multiple key publics for NASA. In one example, during the opening statement at a space subcommittee meeting for the House Science, Space and Technology Committee in October 2015, Rep. Brian Babin talked about heightened public interest in Mars exploration stemming from *The Martian* and noted that:

> "Last week was an amazing time for the space community. A major Hollywood film about the exploration of Mars debuted within days of NASA announcing a significant scientific discovery – liquid water on Mars. The coincidence of these two events garnered the public's attention, and rightly so. Rarely does popular culture and science align in such a serendipitous fashion" (Babin, 2015, p. 1).

Meanwhile, Chairman Lamar Smith said:

> "The American people are fascinated with space exploration. Just last week, the discovery that water sometimes flows on Mars' surface made headlines across the world. And the latest space film, The Martian, has sparked questions about when NASA will send astronauts to Mars" (Smith, 2015, p. 1).

Serendipity aside, in this period uncertainty appeared rife within NASA in terms of the agency's ability to make and carry out long term plans. Dan Dumbacher, a Purdue University professor and former Deputy Chief of Human Exploration programs for NASA testified during the hearing about the management and morale problems created by recurring budget battles. He said that progress along the journey to Mars was threatened by budget uncertainties and policy debates (Dumbacher, 2015). *The Martian* it seems appeared at a time where confidence in the agency's ability to reach Mars badly needed to be reinforced with both internal and external audiences. To that end, NASA conducted an overt social media and traditional media campaign to highlight the parallels between the film and the agency's journey to Mars. If we return to Hellsten and Nerlich's description (emphasis added):

> "*Sudden and parallel increases* in communications in various discourses (e.g. medical journals, newspapers and discussion groups) point toward connected fluctuations in public debates and possibly to a *purposeful use of public hypes to advance scientific research* in a specific field" (2008, p. 10).

In this context, hype can be cast as a tool which allows for (subtle or overt) building of momentum for research agendas. Hype can be regarded as a tool for agenda setting when looking at how organisations prime their audiences by making a topic more salient. Within this chapter, hype in the form of certain expectations and visions for a human presence on Mars has been used to imagine and fight for an imaginary in which NASA is centre stage in new developments in space exploration. Here, sudden and parallel increases in communications in the forms of press releases, media coverage, lobbying, and a popular film point towards a connected and coherent campaign to advance NASA's version of humankind's future activity in space.

The Martian as a diegetic prototype

Popular culture, such as films, can act as prototypes for science and technology futures. As outlined in the first section of Chapter 2, diegetic prototypes demonstrate the viability and potential of emerging science or technology to large audiences through film (Kirby, 2013). These prototypes are "cinematic depictions that demonstrate a technologies utility, harmlessness, and viability" (Kirby, 2013, p. 195) and represent an opportunity to enhancing funding and promote a research agenda (ibid).

For a risky and expensive field like human space exploration, film has played an essential role in linking to societal benefits and building popular narratives. David Morrison, then head of space research at NASA's Ames Research Centre, believed that films were tantamount to public service announcements. On the topic of the film *Deep Impact*, he remarked that:

> "It [*Deep Impact*] may do more to alert the public to the impact hazard than anything in the past. And its images may even keep you up at night wondering if we are doing enough to protect our planet against this threat" (Kirby, 2013, p. 170).

Similarly, NASA spokesperson Bobbie Faye Ferguson explained NASA's involvement with fiction during an interview in 2000 saying:

> "One of the things we do is try to increase awareness of space and spatial exploration... I certainly think that participating in films reach a large number of people, and that are feasibly fictional, increases the awareness of space and the future" (Kirby, 2003, p. 267).

By supporting *The Martian,* NASA may be looking to more than the short-term gains of re-engaging their publics with space travel (Zhang, 2015). As one journalist remarked "if you want to understand why it is that NASA loves The Martian and is so gung ho for this movie, you have to realize that this movie more or less presents exactly their future vision" (Bradley, 2015, para. 4). This presents an interesting angle for further research in the decades after *The Martian*'s release in cinema to find out whether NASA has achieved a *2001: A Space Odyssey*-sized impact on popular culture. In this context, *The Martian* arguably acts as a diegetic prototype for NASA's Journey to Mars proposal (Kirby, 2013). In the first instance, the timing of the film matches closely with NASA's promise of human exploration of Mars by the 2030s. In one blog post, the agency went as far as comparing milestones between the movie (set in the 2030s) and their current progress.

The technology depicted within *The Martian* also coincides with NASA activity. When the space agency aided *The Martian* team throughout production, part of this assistance included a tour of the NASA Johnson Space Center for the production designer Arthur Max (Rosen, 2015). One of the elements Max was particularly interested in was the habitat or 'hab' which Watney lives in on the surface of Mars. The design of the habitat subsequently produced for the film was inspired by the Human Exploration Research Analog (HERA) in which crews train for long-duration deep space missions. At least nine technologies in the

film have real-life NASA prototypes. The other technologies mirrored within the film include a food crop aboard the International Space Station, a Water Recovery System, an Oxygen Generation System, and prototype spacesuits suitable for use on Mars. NASA actively drew parallels between these technologies and technology in *The Martian* through press releases, blog posts and social media.

The Martian provides an explicit example of how NASA has worked to portray its vision of human exploration of space. The film narrative precisely parallels timelines put forward by the agency and portrays nine technologies that are currently in development. To understand the Journey to Mars campaign more broadly, my analysis now turns to the metaphors presented within press releases, media coverage, and lobbying documents.

Method: The humans to Mars campaign

The newer a research field or the further away the actualisation of a technology is, the more hype is necessary for agenda setting. In his discussion of hype in relation to the 'dynamics of expectation', Brown corroborates this when he identifies two key elements that influence the use of hype: the temporal and spatial setting. In the case of *The Martian* and NASA's broader campaign for human exploration of Mars, the temporal setting is particularly significant. For NASA's journey to Mars, a mission which is unlikely to materialise in full before 2030 at the earliest, hype seems unavoidable if the agency is to secure the necessary public interest and policy support.

As outlined during an exploration of the performativity of expectations within Chapter 2, Borup et al. contend that "novel technologies and fundamental changes in scientific principle do not substantively pre-exist themselves, except and only in terms of the imaginings, expectations and visions that have shaped their potential" (2006, p. 287). This characterisation echoes the premises of Kirby's diegetic prototype by, on some level, attempting to establish the viability of an anticipated technology or field of research. Crafting expectations in order to encourage publics to expect particular futures is a part of agenda setting. As identified in Chapter 2, this case study examines future expectations for human exploration of Mars and, in doing so, helps address a gap in the science communication literature on this role of expectations by drawing on STS and public relations.

In this case study, I continued to draw on Jasanoff and Kim's concept of sociotechnical imaginaries to explore the construction of a future in which humans step foot on Mars (2015). Jasanoff and Kim (2015) provide an overview of the methods a researcher might use to analyse and gain understanding of a sociotechnical imaginary. These include interrogating the construction of stories of progress, comparisons of issue framing over time, and tracing uses of symbolic and cultural resources such as language and metaphor. Here, metaphors act almost as miniature stories that, when reviewed on a whole, provide a vision of a desired future.

In this example of hype in science, NASA has worked to set an explicit agenda for human exploration of Mars through popular science and a coordinated media campaign. The agency has drawn a direct line from its legacy – past achievements and cultural presence – through to present work and visions of their desired future. The sociotechnical imaginary advanced here by NASA and its supporters is visible in the sudden and parallel increases in communication activity around the human exploration of Mars in media coverage, *The Martian*, and political discussion at the space subcommittee meeting for the House Science, Space and Technology Committee. This communication activity is analysed here in terms of the metaphors used to describe and support NASA's desired future.

Conceptual metaphor analysis

As previously discussed in Chapter 2, metaphors play a significant role when they are used to mediate meaning across different contexts (Leydesdorff & Hellsten, 2005). They also have significant rhetorical power in that they provide overarching narratives and can travel between different forms of communication (Hellsten et al., 2014).

Rather than being merely a feature of "poetical imagination and the rhetorical flourish", metaphors are a part of ordinary language (Lakoff & Johnson, 1980). As argued by Lakoff and Johnson, metaphors are pervasive in everyday language and they influence the way we think, speak, and act. As an example, consider the metaphorical concept "TIME IS MONEY". This metaphor is reflected in everyday English phrases, such as: "I *lost* time while I was sick", "How do you *spend* your time?", and "This error *cost* me three hours". This particular conceptual metaphor speaks to the way we think about time, as a "limited resources that we use to accomplish our goals" (Lakoff & Johnson, 1980, p. 8). As in this example, identifying conceptual metaphors can tell us much about how a particular topic –

for this thesis, science and technology developments – is considered in the present and how it might be positioned for and in the future. More recent research on discourse metaphors has shown that relatively stable metaphors can function as "key framing devices with a particular discourse over a certain period of time" (Zinken, Hellesten, & Nerlich, 2008, p. 243). Discourse metaphors are "conceptually grounded but their meaning is also shaped by their use at a given time and in the context of a debate about a certain topic" (Nerlich & Jaspal, 2012, p. 134). These framings can have political and performative impacts on discussion surrounding issues.

Metaphors play a significant role in meaning mediation across different contexts (Leydesdorff & Hellsten, 2005). They provide overarching narratives and are 'nomadic' in that they travel between different forms of communication and different fields (Hellsten et al., 2014; Maasen & Weingart, 1995). For instance, Nerlich and Hellsten (2004) argue that we can "take concepts from other cultural areas, such as literature and linguistics, to make sense of complex issues, such as genetics and genomics" (p. 258). In discussion on the effect of metaphors for genomic discourse, evolutionary biologist John Avise noted "metaphors in science are like foghorns and lighthouses: They usually reside in treacherous areas, yet they can also guide research mariners to novel ports" (Hellsten & Nerlich, 2008, p. 258). Ideally, Avise says, metaphors make the unfamiliar accessible and provide the chance for making connections that are not otherwise apparent. He also warns of a danger that the metaphor can "restrict rather than expand research horizons" (ibid, p. 258).

The following qualitative analysis of the corpus built on methodologies adopted by Hellsten et al. (2014) and Hellsten et al. (2012), which involve semantic word analysis and metaphor analysis. In their 2014 paper, Hellsten, Porter and Nerlich examined how different meanings in the media create future expectations around climate change through semantic co-word analysis and metaphor analysis. Their study focused on the types of futures constructed through use of metaphors representing hope, progress and solutions as opposed to metaphors representing hopeless and disappointment. In their concluding remarks, the authors called for more research into representations of constructed futures.

Similarly, Nerlich and Jaspal (2012) used qualitative metaphor analysis to identify the metaphorical framings with the most significant political and performative force in the discussion around geoengineering. This decision process for identifying metaphors in this paper was based on older research into conceptual metaphors (Lakoff & Johnson, 1980) and

more recent work on discourse metaphors (Zinken et al., 2008). The metaphors isolated in this case study provide a way of making connections that were not readily apparent otherwise. They articulate a unifying storyline for press releases and media coverage that stretched across three years and multiple separate announcements from NASA and other actors. The analysis conducted here also draws on a proposal from Hellsten et al. (2012) for automated analysis of the evolution of frames and metaphors. This proposed approach is designed to deal with large amounts of text and contributes to the issue of increasing amounts of data in science communication research (ibid). The decision process for identifying metaphors was also influenced by Hellsten et al. (2012) who were principally concerned with implicit metaphors. For instance, the journey metaphor that is implicit within phrases such as 'progress' and 'steps towards the future'.

The automated analysis program used in this case study is called *Leximancer*. This program allows researchers to map themes, concepts, and associated relationships within text. By using the original material and not being dependent on the interpretation of an analyst, Leximancer achieves a high-level of reliability and repeatability (Smith & Humphreys, 2006). The software groups sentences into blocks to generate its text-based statistics, which include rank-ordered concept lists to indicate the strength of relationships between tags and concepts (van Vuuren, Angus, & Ward, 2014). As well as generating these statistics, Leximancer represents concepts from the text in a two-dimensional map, with information grouped into nodes (also known as themes) and lines to connect related concepts. The larger the size of a theme, the more prominent that concept is within the data (van Vuuren et al., 2014). This automated approach, enabled by Leximancer, allowed for the identification of consistent metaphors within the texts as well as the examination of the relationships of the texts themselves.

For guiding the interpretation of the highly detailed and dense maps produced by Leximancer, I focused on shared sets of words and concepts amongst the data set (Hellsten et al, 2012). This also helped with the identification of any agenda setting which occurred during the campaign, which is to say that if agenda setting did take place then words and/or concepts within the press releases would be expected to appear within the media coverage.

To take a closer look at how future expectations are constructed for NASA's Journey to Mars, I examined the metaphors present within press releases and media coverage from 2014 to 2016. The corpus for this chapter comprises of the press releases issued by NASA on

Mars between January 1, 2014 and December 31, 2016 (n = 129). The media coverage examined in here is a purposive sample for the same timeframe (n = 287).

A Google search for the terms 'NASA' and 'Mars' returns over 72 million results, which could reflect the high quantity of popular culture artefacts centred on the red planet or it might reflect the content generated over the past decades during NASA's missions on Mars. NASA's attempts to launch flybys to Mars started in the early 1960s and a sustained program of robotic exploration of the planet (the Mars Surveyor Program) commenced in 1996. Archived on the NASA website are 577 press releases from the same timeframe (1996-2016), which specifically mention Mars in the title or first two lines of the release. For this chapter, 129 press releases were downloaded from the NASA website. In terms of media coverage, online news articles were downloaded from what is arguably the most diverse and thorough collection of online media coverage – Google News – using the search terms 'NASA' and 'Mars.' Articles were downloaded from Google News until saturation was reached. To ensure relevance, all articles were browsed before being downloaded. They were sourced from a range of traditional (for example, the New York Times) and online media outlets. This corpus of press releases and media coverage was selected to investigate when and how metaphors were presented within press releases and subsequently transferred to media coverage. The 2014-2016 timeframe encompasses the launch of the official Journey to Mars campaign by NASA in October 2015, the release of the film *The Martian* in the same year, and the gradual introduction of more industry-centric messaging during 2016.

In addition to the press releases and media coverage, annual reports issued by *Explore Mars* in 2015, 2016, and 2017 in addition to a "Why Mars?" publication from 2017 were analysed to allow for a comparison between the metaphors used by NASA in press releases and the metaphors used by the lobbying group. This aspect of the analysis represents a small portion of lobbying around human exploration of Mars and can most accurately be regarded as a snapshot of lobbyist activities.

The metaphors identified in the corpus acted as miniature stories which, when integrated through the overarching conceptual framework of the sociotechnical imaginary, provided a vision of NASA's desired future. In the next section, I present the analysis of the corpus and outline the broad themes that emerged around NASA's journey to Mars.

Data analysis: Metaphors for Mars

The Leximancer analysis provided an overview of key themes within the corpus. This section begins with the Leximancer analysis of NASA press releases and media coverage before outlining the broad themes that emerged from the qualitative metaphor analysis of the corpus. I then interrogate the way individual metaphors were operationalised. Based on the broad themes, NASA's campaign for human exploration of Mars was chiefly conceptualised in terms of JOURNEY, a COMPETITION, a spatial orientation metaphor FORWARD, and WAR. This section also examines the metaphors shared between the press releases and media coverage with documents published by the lobby group *Explore Mars*.

Press releases

NASA published 129 press releases that explicitly mentioned Mars between 2014 and 2016 (2014 n=53; 2015 n=55; 2016 n=21). Across the three years the content of the press releases was chiefly concerned with several similar concepts, which might be explained by the longevity of pure research programs and NASA's long-term focus on human space exploration. The use of the phrase "Journey to Mars" increases over the three years. The year that saw the most frequent use of the phrase (2016) was also the only year in which the phrase appeared on the Leximancer-generated concept map. The subject of the releases was generally new information transmitted by NASA's robotic explorers. The language often framed in terms of the journey to Mars and establishing a pathway for human explorers. This may have been done in an attempt to make some of the more abstract data relatable and shareable.

Figure 1: Leximancer map - Press releases 2014

Press releases 2014: The Leximancer map in Figure 2 shows all 53 press releases from 2014 plotted together. Eleven thematic groups were identified in all. They were: Space, NASA, Mars, mission, crew, Martian, during, design, challenge, impact, and SLS. The most important themes were space, NASA, and Mars. In the map produced for 2014, the concepts (indicated by the black text) are more densely clustered around the core theme (the red circle) of space. Within the space theme, key words included: research, development, spacecraft, astronauts, human, future, and exploration.

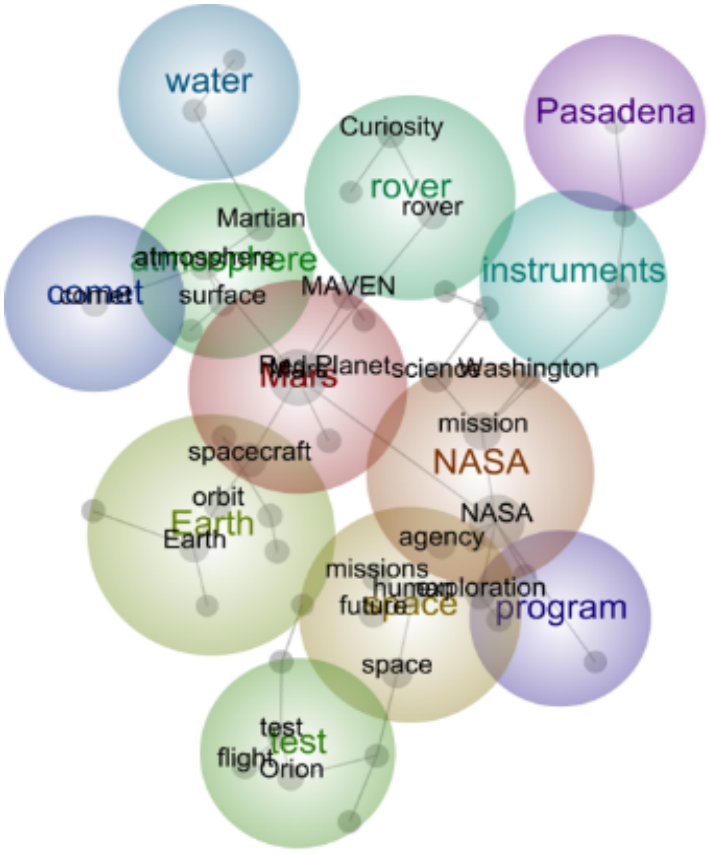

Figure 2: Leximancer map - Press releases 2015

Press releases 2015: The Leximancer map in Figure 3 shows all 55 press releases from 2015 plotted together. Twelve thematic groups were identified for this year. They were: Mars, NASA, space, Earth, atmosphere, test, instruments, rover, water, program, comet, and Pasadena. The most important themes were Mars, NASA, and space. In contrast to the 2014 map, concepts within the 2015 map were less densely clustered around the core theme of

Mars. Amongst the top three themes (red, orange, and yellow circles), key words included: Red Planet, spacecraft, mission, NASA agency, human exploration, future, and space.

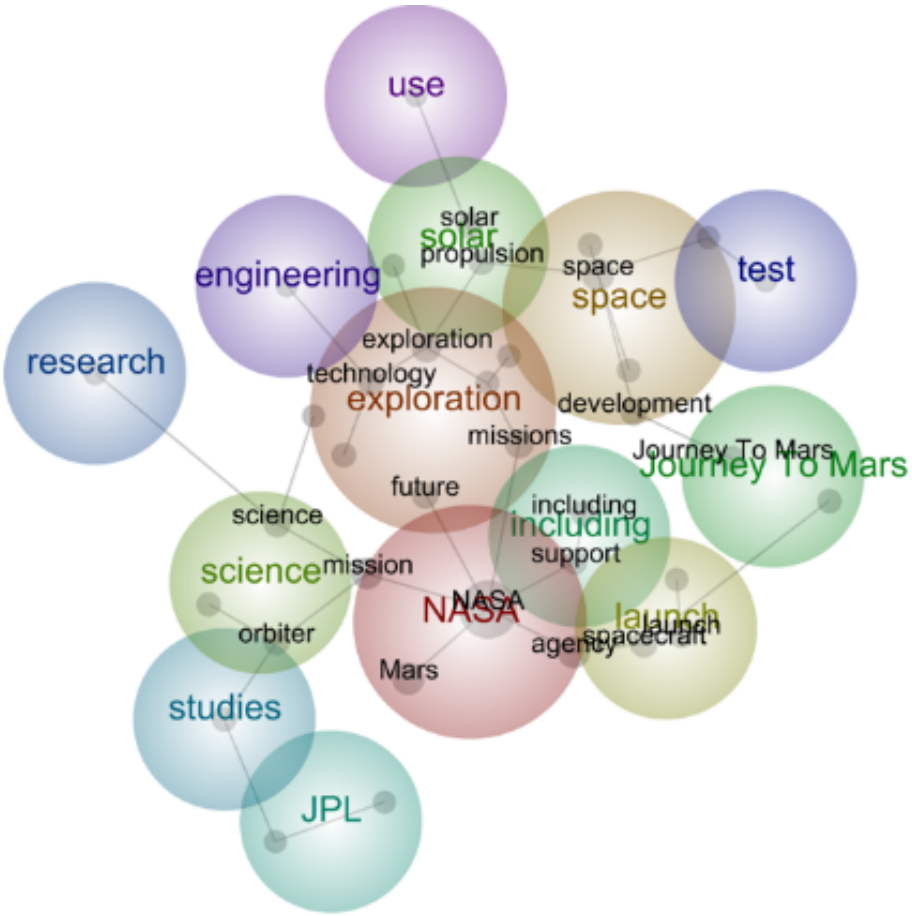

Figure 3: Leximancer map - Press releases 2016

Press releases 2016: The Leximancer map in Figure 4 shows the 21 press releases from 2016 plotted together. Fourteen thematic groups were identified. They were: NASA, exploration, space, launch, science, solar, Journey to Mars, including, research, studies, JPL, engineering, use, and test. The most important themes were NASA, exploration, and space. In the 2016 map, key words within the most important themes (also the red, orange, and yellow circles) were: Mars, NASA, agency, future, missions, technology, exploration, space, and development.

Two themes were consistently highlighted across 2014, 2015 and 2016: "NASA" and "space". In 2014 and 2015, "Mars" was the third dominant theme, though 2016 saw "Mars"

exchanged for "exploration." Across each year, "NASA" was portrayed through its administrative functions – chiefly concerned with overseeing technology development, recruitment, and public-private partnerships. "Space" was depicted as a challenging, risky environment; and an exciting endeavour for pioneering astronauts. "Mars" presented a focus for deep space explorers and future robotic missions; in relation to the concept of "Mars", the corpus highlighted both current and past research endeavours. "Exploration" emphasised the ambitious nature of the past moon program, and highlighted planning for future deep space exploration with explicit mention of commercial partnerships.

Media coverage

During this case study, 287 articles which explicitly mentioned NASA and Mars were retrieved from Google news between 2014 and 2016 (2014 n=46, 2015 n=107, 2016 n=134). Across the three years, "Mars" was a dominant theme in the Leximancer maps with "NASA" and "space" as other significant themes.

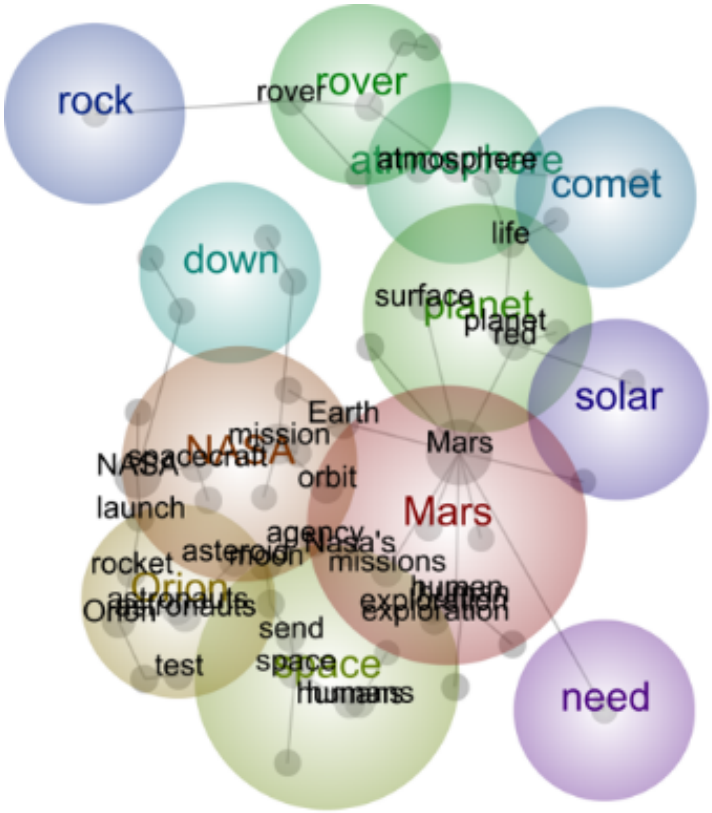

Figure 4: Leximancer map - Media coverage 2014

Media coverage 2014: The Leximancer map in Figure 5 shows the 46 news articles from 2014 plotted together. Twelve thematic groups were identified for this year. They were:

Mars, NASA, Orion, space, planet, atmosphere, rover, down, comet, rock, solar, and need. The most important themes were: Mars, NASA, and Orion. The key words for the 2014 map were densely clustered amongst these more important themes (red, orange, and yellow circles). They were: Mars, NASA's, missions, human, exploration, Earth, mission, orbit, asteroid, moon, spacecraft, launch, rocket, astronauts, Orion, and test.

Figure 5: Leximancer map - Media coverage 2015

Media coverage 2015: The Leximancer map in Figure 6 shows the 107 news articles from 2015 plotted together. Twelve thematic groups were identified. They were: Mars, space, surface, time, team, water, work, exploration, test, down, crew, and astronaut. The most important themes were: Mars, space, and surface. The key words in the 2015 map were less densely clustered than in the 2014 map. In the most important themes (red, orange, and yellow circles) the key words were: Mars, science, NASA, Red Planet, missions, agency, human, astronauts, space, orbit, surface, planet, Martian, scientists, Curiosity, and rover.

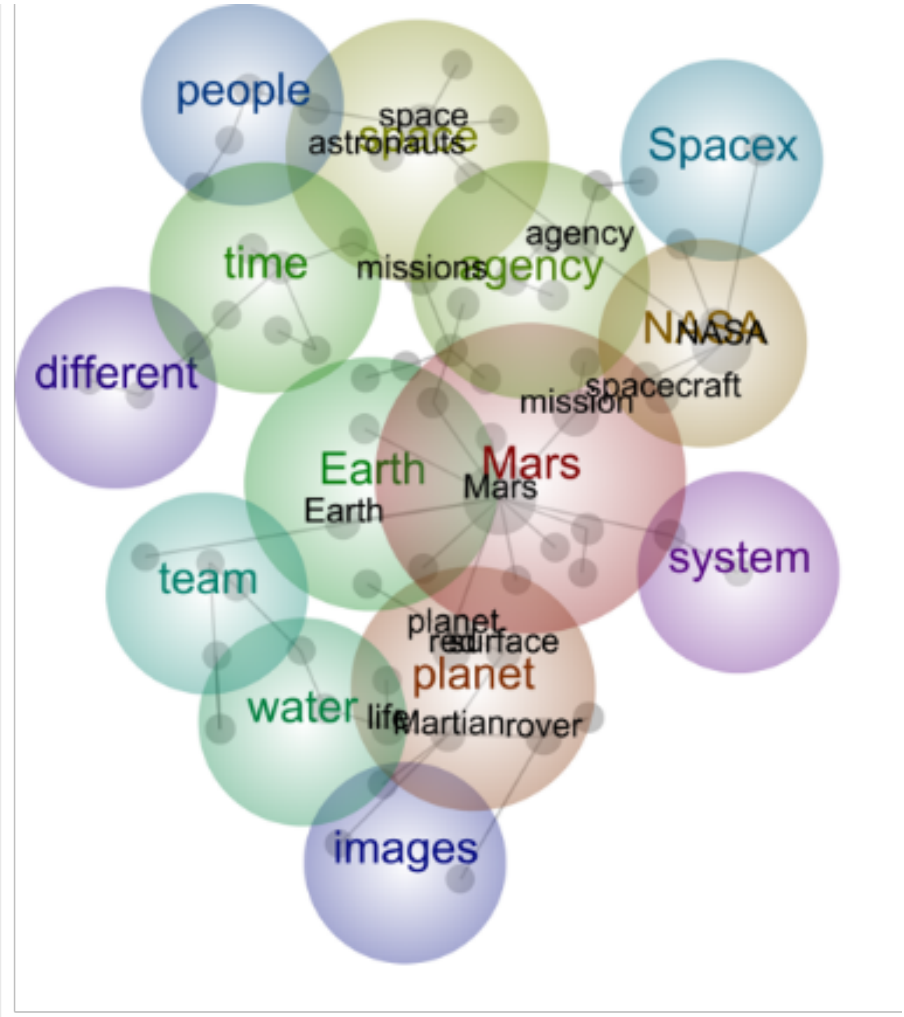

Figure 6: Leximancer map - media coverage 2016

Media coverage 2016: The Leximancer map in Figure 7 shows the 134 news articles from 2016 plotted together. Fourteen thematic groups were identified in all. They were: Mars, planet, NASA, space, agency, time, Earth, water, team, SpaceX, people, images, different, and system. In contrast to the 2014 and 2015 news article maps, the key words for 2016 were the most distributed among the thematic groups. The most important themes of Mars, planet, and NASA (red, orange, and yellow circles) contained the following key words: mission, spacecraft, NASA, planet, surface, Martian, rover, and life.

From 2014 to 2016, "Mars" was consistently presented as an inevitable goal for human spaceflight while current robotic exploration was chiefly discussed in terms of laying the groundwork for human exploration of the planet. "NASA" was principally conceived of as an organiser of space exploration with large-scale initiatives and strategic partnerships; an enabler whose principal role is to collect and justify funding for long term space exploration.

"Space", and human activity in space, was predominantly discussed in terms of the challenges associated with achieving sustainable human habitation and a need to 'get back on track'. Within the three years, there was a noticeable shift towards industry with the involvement of Mars One and SpaceX. Media coverage was more likely to include outside sources in addition to information from NASA. Initial reports in 2014 were largely favourable with more critical tone regarding progress along the "path" to Mars appearing in 2015 and 2016. Despite the increasingly critical tone, the journey to Mars was still depicted as ambitious and worthwhile.

Comparison of press releases and media coverage

Discussion of water on Mars in news articles from 2015 and 2016 aligns with the content of NASA press releases in 2015. These 2015 press releases coincided with the launch of *The Martian* in the United States and primed audiences for the film, which highlighted a crucial challenge for establishing a human presence on the planet – the need for water to sustain human lives. Meanwhile, emphasis on the human component of space exploration within the press releases despite the continued presence of robotic explorers (for instance, the appearance of the rover theme in Figure 4) reflects NASA's efforts to link current research and development with eventual human spaceflight. This ties into previous work (Cokley & Angus, 2014). In contrast to the emphasis within NASA on agency-centric work, news articles were more likely to link individual updates to the broader context of space exploration (for instance, the SpaceX theme in Figure 6). News articles also focused more on the human angle of space exploration (for instance, astronaut theme in Figure 5 and people theme in Figure 6).

Metaphor one: JOURNEY

Hellsten et al. write that "metaphorising public issues in terms of steps taken is an effective way of binding the present… to the future" (2014, p. 477). In light of the name of the NASA campaign for human exploration of Mars ('Journey to Mars'), it was unsurprisingly that the JOURNEY metaphor was frequently adopted in press releases. As per the Leximancer concept maps (Figures 1-3), the actual phrase 'Journey to Mars' was not used often within 2014 and 2015 releases. However, the campaign framing consistently referred to the 'next step' for human exploration as being centred around establishing a human presence on

Mars. This framing also appeared within the media coverage (Figures 4-6) with human spaceflight to Mars presented as a near-term focus, a path, a journey that would be paved by NASA, and a pioneering quest pursued by the agency and its champions. The journey-centric phrases adopted often highlighted milestones, progress, or steps along the 'ambitious journey' to Mars. What follows is a sample of data, across the years of the NASA campaign, to provide a sense of how the metaphors emerged during the data collection period.

The JOURNEY metaphor was used to conceptualise scientific and political developments in terms of progress or steps towards the future:

> "Maven… is another NASA robotic scientific explorer **paving the way for the journey to Mars**" (PR 2014, September 19 – "NASA launches new citizen science website; opens challenge to participate in future Mars missions"); "The information being gathered about Mars… [is] **paving the way for future human missions** on a **journey to Mars** in the 2030s" (PR 2014, December 18 – "NASA, Planetary scientists find meteoritic evidence of Mars water reservoir"); "Today, our **robotic scientific explorers are paving the way**, making great progress on the **journey to Mars**... Together, **humans and robotics will pioneer Mars** and the solar system." (PR 2015, May 28 – "NASA begins testing Mars landing in preparation for next mission to Red Planet"); "NASA is **another small step closer to sending astronauts on a journey to Mars**." (PR 2015, September 9 – "First pieces of NASA's Orion for next mission come together at Michoud"); "NASA is on an **ambitious Journey to Mars** that includes sending humans to the Red Planet in the 2030s. The agency's robotic spacecraft are **leading the way**." (PR 2016, August 17 – "NASA television airs Journey to Mars showcase, rocket engine test"); "**...**to talk about the science and technology aboard NASA's next Mars rover, Mars 2020, and the **significant step** the agency is taking on its **Journey to Mars**" (PR 2016, July 16 – "NASA to discuss next Mars rover on Facebook Live").

The media coverage did not always reflect positively on NASA's campaign to Mars. Nonetheless, journalists frequently adopted the JOURNEY metaphor when creating links between individual events during 2014-2016. Within the media coverage, the JOURNEY

metaphor conceptualises external views on NASA projects as leading towards human exploration of Mars:

> "NASA video reveals **the steps needed to transport humans** to the red planet by the 2030s" (Daily Mail, April 30 2014 "How man will land on Mars: NASA video reveals the steps needed to transport humans to the red planet by the 2030s"); "The hearing, called 'From Here to Mars,' outlined intermediate space missions being planned as **steps toward long-duration space travel**." (Daily Mail, April 30 2014 "How man will land on Mars: NASA video reveals the steps needed to transport humans to the red planet by the 2030s"); "There are plenty of challenges to overcome on the "**journey to Mars**", not the least of which is NASA's flatlining budget. But going to Mars would be pretty sweet." (Popular Science, 10 December 2015 – "5 Exciting Technologies NASA's Developing So We Can Make It To Mars And Back"); "Like the Apollo program, we embark on this journey for all humanity, NASA said in a report called **Journey to Mars**. Unlike Apollo, we will be going to stay." (Inquirer.net, 17 November 2016 – "NASA targets to establish human colonies on Mars by 2030s"); "The human factor of exploring the nearest stars and exoplanets would be a profound **voyage for humanity**, one whose non-scientific implications would be enormous," writes Lubin. "It is time to begin **this inevitable journey beyond our home**." (ScienceAlert, 22 February 2016 – "NASA Researchers Are Working on a Laser Propulsion System That Could Get to Mars in 3 Days").

The JOURNEY metaphor represented in the data samples above presents the NASA campaign to Mars as an ongoing, inevitable process rather than a series of individual projects. In the next metaphor, that JOURNEY becomes a COMPETITION with the end goal of putting a human presence on the red planet.

Metaphor two: COMPETITION

For this metaphor, the press releases and media coverage drew on the concept of competing in a race or rivalry to understand NASA's Journey to Mars. As demonstrated by the data samples that follow, the conceptualisation of the COMPETITION metaphor emerged over three years through language that measured the success and failures of NASA projects.

Within the press releases, the COMPETITION metaphor most often referred to achieving 'goals' in pursuit of achieving human presence on Mars:

> "This is another great example of American companies partnering with NASA to enable our **future exploration goals**." (PR October 17 2014 – "New commercial rocket descent data may help NASA with future Mars landings"); "The joint Mars Working Group will seek to identify and implement **scientific, programmatic and technological goals** that NASA and ISRO have in common regarding Mars exploration." (PR September 30 2014 – "US, India to collaborate on Mars exploration, earth-observing mission"); "This strategy charts a course **toward horizon goals**, while delivering near-term benefits" (PR October 9 2015 – "NASA releases plan outlining next steps in the Journey to Mars"); "This next group of American space explorers will inspire the Mars generation to reach for new heights, and help us **realize the goal of putting boot prints on the Red Planet**, said NASA Administrator Charles Bolden." (PR November 5 2015 – "Be an astronaut: NASA seeks explorers for future space missions"); "Today, we are publishing additional details about our journey to Mars plan and how we are aligning all of our work **in support of this goal**." (PR October 9 October 9 2015 – "NASA releases plan outlining next steps in the Journey to Mars"); "**The goal of the research** is to produce promising new approaches, treatments, countermeasures or technologies that have practical application to spaceflight." (PR July 21 2016 – "NASA establishes institute to explore new ways to protect astronauts"); "During the next 18 months, the directorate will release more solicitations with **the goal of making significant investments** that address high-priority challenges for achieving safe and affordable deep-space exploration." (PR March 15 2016 "NASA selects proposal to build better solar technologies for deep space missions").

The media coverage used the COMPETITION metaphor in a similar manner to press releases with additional reference to the previous Cold War-era space 'race'. The articles also highlighted the different approaches taken by NASA and its 'competitors' in industry:

> "Humans on Mars as soon as 2037 should be **NASA's goal"** (4 June 2014 – Scientific American "Humans on Mars as soon as 2037 should be NASA's goal: panel"); "But the NRC reviewers argue that NASA and its international partners should focus on

> the **horizon goal of Mars** and do whatever it takes to get there, step by step, avoiding changes in strategic direction." (4 June 2014 – Washington Post “NASA strategy can’t get humans to Mars, says National Research Council spaceflight report”); "Putting astronauts, followed by homes, on the red planet is **one of NASA's biggest goals for the decades to come a goal the organization hopes to make crucial strides toward in 2016,** according to NASA's Chief Scientist Ellen Stofan." (26 December 2015 – News Week “NASA to-do list 2016: Mars”); "The consensus among space policy analysts is that a NASA mission to Mars with astronauts would require a political mandate that currently does not exist. This is not the 1960s, when the agency's budget spiked in **a race to beat** the Soviet Union to the surface of the moon." (2 October 2015 – Washington Post “Don’t worry. Matt Damon won’t get stuck on Mars. NASA can’t get him there”); "NASA's **game plan** might seem a little slower, and it certainly packs less bravado, but it's also delivering solid results" (11 October 2016 – ScienceAlert, “Obama just explained how NASA will get humans to Mars by the 2030s”); "We have set a **clear goal** vital to the next chapter of America's story in space: sending humans to Mars by the 2030s and returning them safely to Earth, with the ultimate ambition to one day remain there for an extended time" (11 October 2016 – CNN “Barack Obama: America will take the giant leap to Mars”); Musk does, by virtue of his single-minded dedication to the **goal** of putting people on Mars (rather than making a profit or playing pork-barrel politics) and the advantage that SpaceX is a 21st-century company, not a 20th-century bureaucracy" (28 September 2016 – Air & Space Smithsonian “Did SpaceX just pass NASA on the road to Mars”).

For the COMPETITION metaphor, the most common phrasing looked at whether NASA was hitting or setting "goals" in their course towards Mars. The following metaphor then positions NASA’s focus on Mars as a part of how the agency will progress into the future.

Metaphor three: FORWARD

Lakoff and Johnson define orientational metaphors as "metaphors [that] give a concept a spatial orientation" that are determined by "our physical and cultural experience" (1980, p.

14). The sample of data that follows shows how the spatial orientation metaphor FORWARD was used in press releases and media coverage orient the future *in front* of their audiences. The press releases conceptualise the FORWARD metaphor in terms of progression. The journey to Mars is a massive leap forward (far in the future) that is simultaneously made up of horizon goals (near term):

> "NASA's parallel path for human spaceflight also took a **giant leap forward** in September when the agency announced U.S. astronauts once again would travel to and from the International Space Station (ISS) from the United States" (PR December 22 2014 – "NASA takes giant leaps on the Journey to Mars"); "The agency will continue... to foster groundbreaking technology development and aeronautics; and **move forward** with the Space Launch System and Orion on our journey to Mars" (PR 22 December 2014 "NASA Takes Giant Leaps on the Journey to Mars…in 2014"); "The space station remains the **springboard** to NASA's next giant leap in exploration, including future missions to an asteroid and Mars" (PR 2 September 2015 – "Soyuz heads to Space Station with new crew"); "This strategy charts a course toward **horizon** goals, while delivering **near-term** benefits, and defining a resilient architecture that can accommodate [changes]" (PR 9 October 2015 – "NASA releases plan outlining next steps in the Journey to Mars"); "It's fitting on the 47th anniversary of humanity s first moon landing that we are announcing a new human spaceflight research institute that will help reduce risks for our astronauts on **the next giant leap our Journey to Mars**" (PR 21 July 2016 – "NASA establishes institute to explore new ways to protect astronauts").

The FORWARD metaphor in the media coverage focuses on cultivating an image of the next "giant leap" in human space exploration:

> "NASA's Journey to Mars project intends to send humans to Mars by the 2030s. Engineers and scientists around the country are working hard to develop the technologies astronauts will use to one day live and work on Mars, and safely return home from the **next giant leap** for humanity" (4 October 2015 – Tech Crunch, "NASA Astronauts Can Already Farm On Mars"); "Today, we opened the application process for our next class of astronauts, extraordinary Americans who will take **the next giant leap in exploration.**" (15 December 2015 – The Next Web "NASA seeking

> astronauts for Mars mission apply online"); "And while that won't come in 2016, the year ahead is sure to be filled with small steps by man aimed **toward a giant leap** for mankind right onto the surface of Mars" (26 December 2015 – News Week "NASA to-do list 2016: Mars"); "If they succeed, they can help humankind make **our next giant leap** onto Mars." (17 August 2016 – Eater "How NASA is Solving the Space Food Problem"); "Barack Obama: America **will take the giant leap** to Mars" (11 October 2016 – CNN, "Barack Obama: American will take the giant leap to Mars"); "Mars One is just one of several corporations **vying to take the next giant leap forward** in space exploration" (23 November 2016 – ABC News "NASA, ESA experts insist successful Mars mission decades away").

This FORWARD metaphor emerged from press release and media coverage to focus on taking a "giant leap forward" to Mars and creating the "springboard" for that giant leap. Meanwhile, the fourth and final metaphor originated from media coverage alone and invites discussion around NASA strategic campaign, or their (POLITICAL) WAR, for Mars.

Metaphor four: (POLITICAL) WAR

This final metaphor was not found within press releases. Instead, and as shown by the samples of data that follow, the conceptual metaphor WAR was reflected in the language adopted by journalists in the media coverage corpus alone. In the media articles, journalists used the WAR metaphor to refer to NASA conducting a 'campaign' to create consensus for the journey to Mars:

> "While a two-decade **campaign** to prepare a manned mission to Mars would certainly be expensive, it would cost nothing close to the $1 trillion figure that has sometimes been cited, the panel concluded" (23 April 2014 – National Geographic, "A Mars Mission for Budget Travelers"); "Such a **strategy** would prove out the technologies required to get to Mars orbit, and also dilute the risks and costs of a crewed Red Planet campaign, advocates say" (2 October 2015 – Space.com, "'The Martian' and Reality: How NASA Will Get Astronauts to Mars"); "That Journey to Mars **campaign** has also been supported by the publicity for the film The Martian" (SpaceNews 5 October 215 – "NASA's Humans-to-Mars Plans Win Publicity but Lack Details"); "Now, we have a communications **campaign** that is focused on integrating

> the technology, the science and the human spaceflight aspects of it." (5 October 2015 – Space News, "NASA's human-to-Mars plans win publicity but lack details"); "Mr. Kirkpatrick did point out Mr. Trump's pothole prioritization remark but said ensuring a strong space program could fit into his **campaign** theme of Make America Great Again" (16 October 2016 – Washington Post, NASA's Mars mission on standby for word from next president"); "Not long afterward, NASA rolled out a carefully orchestrated, almost irritatingly earnest marketing **campaign** around the blockbuster film The Martian" (24 February 2016 – Sydney Morning Herald, "Want to fly to Mars? NASA needs 14 new astronauts"); "NASA has been advertising its "Journey to Mars" **campaign**, with NASA Administrator Charles Bolden saying that humans could go to the Red Planet as early as the 2030s" (4 Feburary 2016 – Space.com, "The Moon or Mars? NASA must pick 1 goal astronauts, experts tell congress").

This WAR metaphor was used by journalists to describe NASA's strategic marshalling of attention and support for human exploration of Mars. Interestingly, this metaphor is also found within documents created by the advocacy group *Explore Mars* to characterise various 'battlefronts'.

Explore Mars – lobby group comparison

The following section compares the metaphors identified within the press releases and media coverage with the metaphors used by the lobby group *Explore Mars.* The corpus considered below is small and represents a snapshot of the group's perspective on the viability of human exploration of Mars and their campaigning for this vision. The corpus consists of annual reports issued by *Explore Mars* in 2015, 2016, and 2017 in addition to a "Why Mars?" publication from 2017. The annual reports in question are chiefly concerned with providing a twelve-month review of the "journey" to Mars in terms of science and engineering developments as well as policy changes and public interest. As shown in the data samples that follow, the principal metaphors identified in the analysis above were also present within the documents analysed here.

The JOURNEY metaphor was conceptualised in terms of progress towards the seemingly inevitable human presence on Mars:

> "Major technical and scientific **milestones** must be effectively communicated so that the public and policy makers understand how they advance the goal of crewed missions to Mars" (Humans to Mars report 2015); "More clarity is required about the **intermediate steps** that will be needed for human landings on Mars" (Humans to Mars report 2016); "Nevertheless, through various hearings in early 2016, Congress has also expressed concerns that (1) NASA has not defined a **clear path** of how it will achieve the Mars goal and (2) **steps must be taken** to assure programmatic stability moving into the next administration" (Humans to Mars report 2016); "The prospect of private Mars missions fascinates the public. While MarsOne, a proposed **one-way journey** to the Red Planet, has faded from the public consciousness, SpaceX continues to hint about its own Mars exploration plans" (Humans to Mars report 2016); "Why send humans to Mars? Because as Gene Roddenberry said, "We are on a **journey** to keep an appointment with whatever we are."" (Why Mars? 2017); "There are many compelling reasons why we should undertake this great **journey"** (Why Mars? 2017); "Conditions that make Mars a desirable **destination** for our next giant **steps** as humankind" (Why Mars? 2017).

Explore Mars' reports adopted the COMPETITION metaphor when outlining the goals which need to be achieved to reach Mars as well as historic goals in space exploration:

> "…our destiny is to explore and break new frontiers, and Mars is the next **goal**…" (Humans to Mars report 2015); "Bush, George W. Bush, and Barack Obama all established Mars as the **horizon goal** of the US space program" (Humans to Mars report 2015); "All of these activities have set the **goal** as humans reaching the Martian surface by the mid- to late-2030s." (Humans to Mars report 2015); "Progress has been made toward achieving this **goal**." (Humans to Mars report 2016); "This historic **goal** has become far more realistic than ever before." (Humans to Mars report 2016); "Mars is such a **goal**." (Humans to Mars report 2017); "Of course, Sputnik and the Cold War may have contributed to the drive behind that **goal**." (Why Mars? 2017); "Those emotions power us to do the impossible. So when you're looking for a **goal**, find the one that excites you and your fellow humans the most." (Why Mars? 2017); "We intend that H2MR can help offset these intentions

> and demonstrate that Mars is clearly the most logical **goal** for human exploration" (Humans to Mars report 2017).

The FORWARD spatial orientation metaphor was conceptualised in terms of human exploration of space (historically – the Moon and in the future – Mars) being a giant step and leap forward for humanity:

> "They made small steps on the Moon, but it was a **giant leap forward** for humanity" (Humans to Mars report 2017); "Conditions that make Mars a desirable destination for our **next giant steps** as humankind..." (Humans to Mars report 2017); Mars is the logical next step in human space exploration. Just as the Moon was a **giant step** for humankind in the 1960s and provided generations with inspiration to dream big and do great things, human Mars exploration will do that during my lifetime." (Humans to Mars report 2017).

As in the media coverage, out of the four principle metaphors identified in this analysis, the WAR metaphor was the only metaphor which was conceptualised differently to the press releases. *Explore Mars* documents' presented this metaphor in terms of 'battlefronts' as well as the 'campaign'-focus found in the previous section:

> "This study identified efficient in-space transportation and splitting the cargo and crew transportation as important for a sustained Mars **campaign**" (Humans to Mars report 2015); "Integration of human space flight capabilities with flight-proven robotic ones is a key element of the emerging **strategies** so that a **campaign** of Mars exploration involving both human explorers and supporting robotics can be attained" (Humans to Mars report 2015); "Our goal in this report is to lay out the many reasons why support for a long-term sustainable approach to a **campaign** leading to humans on Mars in the 2030's is an issue that all of our nation's leaders should embrace" (Humans to Mars report 2016); "The 'Mars vicinity and Phobos, followed by mission to Mars surface' **scenario** represents an ambitious **campaign** that leverages most of the capabilities and potential tradeoffs described in the EMC" (Humans to Mars report 2016); "NASA's Journey to Mars includes the Evolvable Mars **Campaign** (EMC), an ongoing series of architectural trade analyses that seek to define the capabilities and elements needed f or a sustainable human presence on

> the surface of Mars" (Humans to Mars report 2016); "2016 saw progress on several **fronts** in the world of Human Factors" (Humans to Mars report 2017); "Momentum toward sending humans to Mars continued to build during the past year with significant developments on multiple **fronts**. Political support in the United States for such missions was reaffirmed in March 2017..." (Humans to Mars report 2017).

Imagining and fighting for a human presence on Mars

Four central metaphors were identified in the press releases, media coverage, and lobbying documents. According to those metaphors, human exploration of Mars is a significant journey, an indisputably worthy goal, a step forward for humanity, and a prize for which NASA fights a political war. The overarching argument in these documents was contained within the journey metaphor and reinforced by the given name of the Mars project, 'NASA's Journey to Mars'. The language was overwhelmingly positive with the rare media article choosing to question the worth of establishing a human presence on Mars. The metaphors within the corpus formed a meta-narrative for continuing publicity and discussion by providing a unifying link between separate announcements and projects. They are representative of how NASA asks us to imagine a future of human space exploration, specifically in terms of the agency's role in the journey. They provide the underlying and interlinking meta-narratives for individual announcements and projects while also informing the agency's broader publicity campaign themes.

In the case of NASA's Journey to Mars, the distance between achieving near-term funding and political momentum and eventually putting the first human footprint on the planet is at the very least counted in decades. Taking into consideration this temporal setting, it is unsurprising that the language adopted within NASA press releases is relentlessly future-focused and devoid of ambiguity. It appears that NASA, if only unconsciously, acknowledges that some measure of sensationalisation is necessary. Where the press releases adopt this mission in the form of painting a view of Mars as a worthwhile and inevitable destination, the subsequent news coverage seems willing to echo the sentiment – particularly where it comes coupled with apparently concrete details, such as the technologies which will accompany human explorers to the planet. The metaphors adopted in the name of putting humans on Mars are exclusive in that the Red Planet is portrayed as the sole target for the next stage of human space exploration. This is despite

the real-time uncertainty as to whether Mars or a return to Earth's Moon will be the initial focus. The lack of ambiguity is most noticeable in documents from the lobby group *Explore Mars*, which goes so far as to explicitly outline the benefits of focusing on Mars over exploration of the Moon.

This metaphor analysis provides an overview of the way NASA press releases and media coverage characterise the journey to Mars. NASA has continually worked to reinvent itself and align its messaging with the concerns of its publics. In attempting to raise awareness and support for NASA's space exploration program, the press releases primed the media coverage with messaging that emphasised the human face of space exploration through popular culture, astronaut spokespersons, and consistently linking smaller, more robotic-focused 'steps' (for example, launching the Mars 2020 rover) with achieving an ongoing human presence in space. With human exploration of Mars being actively "imagined, fought for, … and embraced in the present" (Brown, 2003, p. 17) by NASA and private organisations, it appears that we are witnessing an attempt at agenda setting – in other words, an attempt to render Mars salient for NASA's extensive audiences and its funders. The years represented in the corpus (2014-2016) were positive for NASA. A foundation of press releases on the agency's Journey to Mars created a desirable result – positive, interested media coverage. In 2015, *The Martian* presented a glossy, idealised agency armed with sufficient political and financial capital so as to take astronaut explorers to the red planet five times over. The agenda setting work represented here culminated in discussion at a space subcommittee meeting, which deliberated over whether NASA would send astronauts to Mars and an editorial written by then US President Barack Obama entitled "America will take the giant leap to Mars" (Obama, 2016).

However, events in the years subsequent to the Journey to Mars campaign demonstrate the ever-shifting landscape the agency must contend with in developing and advocating for its visions of a future in space. With the increasingly participation of privately funded groups, hype around putting people into space beyond the International Space Station may amplify. Certainly SpaceX's 2018 launch of the Falcon X rocket – one of the most anticipated rocket launches in recent memory with CEO Elon Musk's own Tesla as the payload – was a masterful public relations stunt. This increased competition, changing priorities for the agency's programs, and more recent conversations in 2018 on US President

Donald Trump's "Space Force" may signal that NASA, yet again, has a very real need to re-engage its audiences.

Conclusion: Hyping human space exploration

Press releases, the media coverage they inspire, and works of imagination all aid NASA's quest of crafting and owning an image of human space exploration. By mobilising the potential future into the present, and by hyping the implications of present-day work, NASA has attempted to build an agenda for the Journey to Mars to the exclusion of other human space exploration efforts.

NASA seems inextricably intertwined with our notion of space exploration. Campaigns such as the 'Journey to Mars' have helped reinforce this. This interrogation of one example of a NASA campaign has shown that complex factors are at work when it comes to charting the course of the future. This analysis shows how NASA has engaged in strategic promotional work – through overt public relations and more subtle collaboration with popular culture – to prime expectations for human exploration of Mars and to underscore the agency's central position in space exploration. NASA has achieved this by drawing a line from past achievements and popular culture representation through to present day promises for future achievements. In this case study, hype is used to attract public attention for NASA's Journey to Mars, specifically to define how NASA's role in human exploration of the red planet is constructed in the future. This 'traditional' science communication approach to hype presents an example of how alternative ways of imagining a science and technology future can be closed down.

The concept of the sociotechnical imaginary helps reflect on the performativity of expectations for the future and show how these visions of the future shape the way society makes sense of science and technology. In the course of promoting NASA's Journey to Mars a select vision of human exploration of space was created. The expectations that informed this vision became part of the social repertoire of journalists and United States' politicians. However, whether these expectations influenced the wider discourse of space exploration remains to be seen, particularly within the context of changing political conditions in the years following the campaign.

Moving on from NASA’s Journey to Mars, in the next chapter I examine how visions for a field of research can shape national approaches to achieving leadership in the second quantum revolution.

Chapter four: Charting the (second) quantum revolution

> *"The challenge of a [quantum technology laboratory] would be to bring quantum technology to market. The potential for revolutionary innovation is enormous and so is the likely return on investment." (Milburn, 1997, p. 180)*

> *"It would be hard to picture the formation of technology developments and innovation without some kind of shared, though flexibly interpreted, cluster of guiding visions." (Borup et al., 2006, p. 289)*

Hype is a means of securing the social change necessary for technological revolution. It "stretches and strains facts and language" to communicate new, sometimes yet unimagined, possibilities (Ritter, 2010, p. 2). Here, the rhetoric embedded within national quantum strategies will be interrogated to show how science and technology actors promote their views on how the future of a field should unfold.

In this chapter, I provide a background on quantum physics and the evolution of its engagement with decision-makers and other publics. This information provides context for my analysis of the rhetoric of three national strategies for quantum science and technology. Then, I describe my methodological approach and analyse data collection from these rhetorical texts in addition to responses provided by interviewees who helped shape the strategies. After interrogating the additional data from interviews, I bring this analysis together to discuss implications for how quantum futures are being shaped as well as the contribution of this case study to the overall thesis.

Quantum physics is an abstract field that presents a raft of possible technological advancements in areas that include internet communications, financial trading, and health and environmental sensing and imaging. While the challenge for researchers may appear to be purely technological (how do we realise quantum machines?), the field also presents social and political obstacles (how do we win support for quantum machines when we don't quite know what they do or when we can build them?). This dilemma echoes the two elements that can act as key predictors of hype: temporal and spatial setting (Brown, 2003). While the temporal element looks to how recent a field is and the timeline for delivering on

its proponents' promises, the spatial element reflects the different expectations held by different groups involved. In the case of quantum physics and quantum machines, the high levels of uncertainty around what the technology looks like and when they might be built means the central challenge is how to maintain political support and investment. For this field, hype seems inevitable.

Despite uncertainty around timelines for delivery, the message from academia and industry is clear quantum engineering is coming into its own as decades of research edge closer to translation to quantum-enabled technologies. In this energetic and increasingly interdisciplinary field, the language is bold and future oriented. The imaginary for this field is founded in revolutionary rhetoric with its best-know application – the quantum computer – is the subject of numerous promises and campaigns as researchers, industry, and government adopt it as the symbol of a new, revolutionary wave of technology. The first 'quantum revolution' led to the development of the laser and the transistor. It also laid the foundation for today's communication and computation technologies. Now, with the technological and theoretical advances of the last two decades, advocates of the field contend that we are approaching a second revolution and early indications are that the technology produced will be disruptive and powerful.

> "Today we are surrounded by technology that owes its existence, directly or indirectly, to the application of quantum mechanical processes… quantum technology is now a serious money-making business" (Davies' forward in Milburn (1997, p. vi)).

When physicist Paul Davies wrote this introduction to Professor Gerard Milburn's seminal work on quantum machines, he predicted that quantum technologies would deliver on undreamt possibilities. These quantum-enabled technologies use physics and engineering to adopt the properties of quantum physics into practical applications. The field was first proposed by Australian physicist Gerard Milburn in the late nineties. Since then, quantum technology has moved from Milburn's initial proposal into a fully-fledged field with significant public and private investment. In fact, "leading the next quantum revolution" is one of the ten big ideas that drive the United States' National Science Foundation's long-term agenda (NSF, 2017) with expectations of wide-ranging impact from quantum technologies informing a narrative that drives increasing support for quantum research and development.

International emphasis on quantum technology has led to significant investment from public and private sectors. Funded initiatives in the United Kingdom include the UK Quantum Hub Network (over USD$400 million over five years), the Netherlands QuTech initiative (USD$150 million over 10 years), the European Union Flagship Quantum Program (USD$1.3 billion over ten years), and China's reported $USD10 billion investment in a quantum lab based in Hefei. This is in addition to the sums invested by private companies, including Microsoft, Google, IBM, and Intel as well as a growing cohort of smaller start-up companies. Alongside this growing investment, national strategies have been launched to help individual regions or countries to consolidate their advantage in the emerging quantum economy. In the past few years, the European Union and United Kingdom have each launched strategies and roadmaps to forecast the delivery of quantum technology. Canada and the United States are now in the process of producing their own. These strategies tell us more than how each nation plans to support and derive benefits from this emerging technology, they also tell us something of underlying sociotechnical imaginaries that drive organisations and countries to back one field and abandon another. Imaginaries begin with the visions of individuals and small groups. They develop into an imaginary when those actors engage in coalition building. For this case study, the visions of individuals and national identities came together in the form of national strategies.

Despite the substantial attention and investment given to quantum technology by researchers, policy makers, industry, and parts of the media, awareness of quantum technology amongst broader publics seems relatively low. One report on quantum computing described a need to communicate more effectively about emerging quantum technologies in the face of "high levels of uncertainty" (Ingelsant, Hartswood, & Jirotka, 2016, p. 7). Recently, the United Kingdom's Engineering and Physical Sciences Research Council (EPSRC) published a study to gauge "what people perceived [about quantum technologies] and how they felt about the potential impacts of new systems, devices, and products" (EPSRC, 2018, p. 1). Prior to this work, the sole analysis of lay engagement with quantum was published by Sciencewise. The resulting report found no previous evidence of efforts to "gather and report on public views and values in relation to quantum technology" (Sciencewise, 2014, p. 7). In the 2018 ESPRC study, participants were recruited to represent the United Kingdom population. For these participants, the word 'quantum' was familiar but there was low knowledge about what quantum or quantum-enabled technologies involved.

This limited exposure seemed to contribute to a general neutrality towards the emerging technology, though excitement and interest increased when the potential impacts for individuals and society were outlined. In terms of governance, participants expressed concern as to the 'inevitable' misuse of the new technology and the potential for privileged access to them causing increased inequity. From a hype-focused perspective, it was interesting to see that participants felt the technologies represented 'incremental improvement' rather than 'new and revolutionary' change. Yet, the awareness and investment in quantum technologies has consistently been accompanied, or perhaps inspired, by hype: future-focused and often sensational rhetoric, centred on promises of technological application and economic gain.

Whereas science communication literature might argue that hype is something to be prevented or avoided, sociotechnical imaginaries present an alternative view. To illustrate this perspective, I start from the premise that these promises for feasible, desirable futures can be used to promote a view of how the future 'should' be and examine the rhetoric that informs established and emerging national quantum strategies for the United Kingdom, Canada, and the United States of America. This cross-national comparison helps identify individual and shared traits within policy discourse and processes of issue framing and agenda setting and provides insight into the imaginaries that shape each nation's potential quantum future.

A quantum technology imaginary

Organising visions play a central role in the formation of new technology ages. Dourish and Bell (2014) emphasise this in their analysis of the visions used to animate and drive forward the field of ubiquitous computing when they write that "the stories, or organising visions… prefaced new realities and new promises, and in doing so they echoed previous technology visions" (p. 1). As outlined in Chapter 2, our technological and scientific futures are shaped by expectations and visions put forward in the present (Birch et al., 2012; McCray, 2013). By interrogating the expectations that inform these futures, we can understand how versions of the future are used to marshal resources, coordinate activities, and manage uncertainty. It is here that the concept of the sociotechnical imaginaries helps us explore the way futures become powerful vehicles that drive stories of progress, policy agendas, and emerging discourses (Jasanoff & Kim, 2015). The people who propagate imaginaries make promises

and advocate on behalf of their field, technology, or ideal. They work to shape a world that can host their future by creating visions of advancement and application while minimising uncertainty. To produce a quantum age, advocates for the field must tackle the uncertainty of unknown applications and vague deadlines by framing expectations within stories of future success (Brown, 2003; Schyfter & Calvert, 2015). In doing so, they shape the new technology by imagining what needs it might meet and how it might be employed (Dourish & Bell, 2014).

The stakeholders involved in this process include researchers and experts, policymakers and funders. These groups are depicted by Caulfield and Condit (2012) within their hype pipeline by charting how different parties become complicit in hype due to pressures, which include the need for funding and the drive to commercialise. In everyday usage, hype refers to extravagant promotion and centres on the idea of exaggeration. The concept is coupled with publicity stunts and can be considered as on par with deception. Where STS literature views promises and expectations as an inevitable aspect of the future-building process, science communication literature normally discusses hype pejoratively. This attitude is generally related to the potential link between hype and deception, and the potential for creating disillusionment or distrust in science (Caulfield, 2004; Maleszewska, 2013; Morrison, 2006). Taking a step back from this perspective, this chapter looks at hype as part of the process of science popularisation, or the way we gather resources and form social and political discourse in support of research agendas (Gregory & Miller, 1998; Lievrouw, 1990). In this area of science advocacy, hype is a tactic that tends to take the form of science that is simplified and sensational. This hype often goes hand-in-hand with projecting extraordinary futures. It is used to build anticipation for new research and emerging technology. Hype inevitably involves some risk as well as opportunity where the chance to build anticipation and support for the field may come at the cost of lost public support if the imagined futures are not made real (Brown, 2003; Brown & Michael, 2003).

Sociotechnical imaginaries provide insight into how the role of science and technology is positioned in different countries (Burri, 2015). For quantum-enabled technology, most applications are perceived as nascent and remain within the domain of the researcher though the quantum computer has been discussed exhaustively for several years. Quantum computers use the rules of quantum physics to encode and process information. The increased processing power of these computers may solve “hard, high-

impact questions in fields such as codebreaking, chemistry, and physics" (Rieffel & Polak, 2000, p. 2). In 2009, quantum computing began to consistently appear on the annual Gartner Hype Cycle for Emerging Technologies – an industry-based model that describes and predicts interest in new technology (Gartner, 2015). Despite significant impact on multiple sectors being anticipated, it has remained at essentially the same point on the cycle. Gartner's analysts have consistently placed the quantum computer in the category of 'more than 10 years' until plateau, or the stage where the benefits of an emerging technology are demonstrated, accepted and the product is commercially available. In 2011, a report by one Gartner analyst noted that:

> "The technology is in the relatively early research stage, but a number of significant advances have been made in the past several years… Any breakthroughs in this topic will probably be based on a certain amount of serendipity; however, the likelihood of a breakthrough occurring will no doubt be increased with higher funding levels" (Tully, 2011, p. 15).

With considerable funding and focused national and private programs for the field (Thew, Jennewin, & Sasaki, 2019), it appears we are witnessing the creation of a future in which we might soon approach the 'breakthrough' point described in the Gartner report above.

Guiding visions for science and technology must allow for "interpretive flexibility" if they are to maintain rhetorical power and appeal (Eames, McDowall, Hodson, & Martin, 2006, p. 367). In line with this, the national quantum strategies analysed in this case study all allow for a 'breakthrough' moment in an adaptable range of quantum technologies. This fits with the international context in which a movement to attain leadership positions has led to multiple private and public bodies creating their own vision for quantum technology. These visions are interactional and highly competitive with each actor attempting to set their own agenda (Borup et al., 2006). As these visions are created, we witness identity construction through the technoscientific visions projected by advocates where the imaginaries become a site of world making and nation building (Jasanoff & Kim, 2015). In turn, the strategies become a way to know and manage the emerging quantum space.

These intense, concurrent and competing discussions around a specific research field are indicative of hype where hype becomes a persuasive tool used for agenda setting (Brown, 2003). Hype contained in visions for future quantum technologies can shape the eventual impact of these technologies.

Responsible research & innovation: The social implications of quantum

Advocates for quantum technologies argue that these technologies have the potential to change the world profoundly. These changes are difficult to predict but may affect areas as diverse as economy, health, and privacy. In consequence, as quantum-enabled technologies approach the near-term horizon, discussion and debate on the social implications of these technologies has begun. The format of this discussion varies but broadly falls under the banner of responsible research and innovation.

Responsible Research and Innovation (RRI) encourages science and technology actors to anticipate and assess the potential implications and societal expectations of their work. There are currently two primary sources of literature for quantum and RRI. The first is a special issue on *The societal impact of the emerging quantum technologies* as published in the *Journal of Ethics and Information Technology* (Vermaas, 2017). The second is a 2018 report commissioned by the United Kingdom's Engineering and Physical Sciences Research Council (EPSRC) and provides the results of a public dialogue on quantum technologies. This report falls under the UK National Quantum Technologies Programme, which has also produced RRI reports on quantum computing and quantum technologies for defence and national security (EPSRC, 2018; Ingelsant et al., 2016).

The special issue highlights five contributions to a "more inclusive societal debate on quantum technologies" by researchers who explore the popularisation of quantum science, the possible impacts of quantum technologies for science, industry, and society, and RRI for quantum within European policy papers (Vermaas, 2017, p. 241). As Vermaas notes in the introduction to the special issue, the potential impacts of quantum technologies are difficult to gauge because the technologies themselves are in the early stages of development. "This does not take away the urgency to discuss these impacts in a societal debate on quantum technologies" (Vermaas, 2017, p. 246). Rather than avoid the discussion altogether, he argues that any societal debate around the technologies should be open. This would allow potential technologies to be added and removed and for new stakeholders to join. The potential impacts of quantum technologies point to why a discussion on the societal implications is necessary; de Wolf (2017) and DiVincenzo (2017) both consider quantum cryptography and quantum computers in his article. In these examples, cryptography presents opportunities for good and bad use; it might be used to protect information from

terrorists but also allow for mass-surveillance. Quantum computers offer significantly increased speeds for search problems or when dealing with large data sets. They are expensive and are likely to, at least initially, be held by a wealthy few nations and companies.

Turning to RRI, Coenen and Grunwald (2017) consider the emerging themes of responsible research and innovation within policy documents from Europe, the UK, and Germany. The European documents – chiefly, the 2016 Quantum Manifesto issued by the European Commission's Quantum Flagship – produces deficit-style public engagement within the context of education and appears less inspired by notions of co-construction of research with civic actors. The manifesto does not explicitly refer to RRI and instead recommends running a "campaign to inform European citizens about quantum technologies and engage widely with the public [and industry] to identify issues that may affect society" (Quantum Flagship, 2016, p. 13). On the other hand, the UK quantum strategy makes explicit reference to RRI with emphasis on a two-way discussion that "promotes science and innovation that is socially desirable and undertaken in the public interest" (EPSRC, 2014, p. 10). Finally, the German report does not explicitly refer to RRI but does stress the "current debate over data security, privacy, and spying underscores the importance of early and comprehensive technology impact assessment" (Leopoldina, 2015, p. 16). Coenen and Grunwald (2017) note the German report includes specific ideas on the input of civic actors and that it "suggests an approach to RRI in quantum technology which is more inclusive and is focused to a less ambiguous extent on broad societal participation than are the approaches outlined in the British documents" (p. 281). This proposition highlights how, even in the early stages, different approaches can shape opportunities to participate for wider publics.

The RRI reports produced in the United Kingdom for the UK National Quantum Technologies Programme explore public attitudes towards quantum technologies and their applications. These reports are the first of their kind for quantum and broadly indicated that quantum technologies were seen to promise a wide range of benefits for individual and society. Quantum technologies that might save or extend lives through healthcare or humanitarian aid and those with the ability to improve national and financial security were the most engaging for participants. The participants in general were initially neutral towards the field with most growing more interested when the potential benefits of the technologies

were explored. The report on quantum computing found that the current "overwhelming issue is simply a high level of uncertainty" and placed an emphasis on communicating more effectively about quantum as a whole and quantum computing specifically (Ingelsant et al., 2016, p. 7). Meanwhile, the report on quantum applications for defence and national security found that there were several areas of potential interest for defence and national security where RRI might help predict implications and disruptions before the technology is widely deployed.

Quantum science has quickly moved from a "specialist theory in physics to a challenging source of new technologies for science, industry, and government" (Vermaas, 2017, p. 241). The expectations around these potential technologies are just now beginning to enter a broader societal discourse, which will necessarily be informed by the strategies and visions articulated by governments and companies as they ramp up investment in the field. This investment will be shaped by the expectations that advocates put forward for quantum technologies as they attempt to set their own agenda for the field.

Performative expectations and rhetoric

To understand the role expectations play in innovation, Brown and Michael suggest a way of looking at expectations over time by noting significant patterns of "extreme revolutionary potential" and "despairing disappointment" (2003, p. 4; Geels & Smit, 2000). Ploeger's study of the US particle physics laboratory Fermilab traces similar activity in reviewing the ongoing rhetorical work of its researchers and administrators (2009). Ploeger notes that the research environment is shaped continuously by rhetorics that "mark the progress of its research, the development of each new technology, and the nature of its relationship with the government and the general public" (p. 30). These rhetorics, she writes, work to establish boundaries, which help to create and claim an identity or vision and reject others. They are both constitutive and strategic. Ploeger goes to state that "physicists working in the national laboratory system are often keenly aware of the impact and importance of their own rhetoric (Ploeger, 2009, p. 84). This chapter extends this awareness of individual and lab-based rhetoric to national strategies, which are working to claim a nation's identity in the quantum space and to put distance between that nation and their self-identified competitors. The comparative approach used here provides a way to interrogate the interaction of scientific research, an emerging industry, and policy (Jasanoff, 2011).

As well as working to establish the position of each nation in the new quantum-based economy, the language within the strategies create visions for each nation's particular quantum future. In their book on sociotechnical imaginaries, Jasanoff and Kim distinguish between imaginaries and media framing, and also between imaginaries and policy agendas. Imaginaries, they argue, are: "less explicit, less issue-specific, less goal-directed, less politically accountable… imaginaries are instrumental and futuristic… they articulate feasible futures" (2009, p. 123). The power of these imaginative visions of the future in terms of guiding policy is further developed by Levidow and Papaioannou (2014) in their exploration of how societal benefits, such as economic competitiveness, growing valuable knowledge, and sustainability, helped channel a specific future for sustainable biofuels while marginalising alternatives. Similarly, Birch et al. (2012) observe that expectations for technoscientific futures are not restricted to technological advancement but are also frequently concerned with economic growth. The emphasis on economic impact is often significant in the quantum space with promises centred around creating a new workforce and suite of products within the burgeoning quantum economy. Emphasis on economic factors is a general trend where economic arguments tend to work persuasively in policy contexts (Schyfter & Calvert, 2015). Greenberg echoes these sentiments in *Science, Money, and Politics* when he contends that, "science and technology, research and development, [have] become essential ingredients of modernism, national power, and public and personal well-being" (Greenberg, 2001, p. 68).

The futures outlined are shown to be imminent as the rhetoric used draws the future into the present (Williams, 2006). Just as Schyfter and Calvert reflect in their discussions on expectations around synthetic biology, this drawing of the future into the present leads to "pressures… to deliver applications and economic growth within very short timescales" (2015, p. 362). The promises and expectations of these visions work at multiple levels simultaneously. Borup et al. (2006) contend that expectations mobilise resources at the level of national strategies, networks and groups, and in the work of the individual. This chapter looks specifically at the macro-level in comparing three national strategies for quantum research and development. As Birch et al. argues, the ramifications of expectations can expand beyond enabling research outcomes as "even though future visions might not necessarily achieve the expected techno scientific outcomes, promotional efforts can reshape institutional and policy frameworks" (2012, p. 2). Each of the national

strategies examined here are at different stages of realisation, starting with the most advanced - the UK National Quantum Technologies programme. The next section lays out the analytical approach used and then embarks on a discussion of the rhetoric contained within these quantum strategies.

Method: Engineering a quantum future

Quantum technologies are currently considered to be a key emerging sector by multiple stakeholders, including government, industry, and academia. The expectations of technical application for this field seem to be homogenous, though how those technical applications will be achieved is still up for debate. In May 2015, the Dutch Ministry for Economic Affairs presented three main motivations for government investment in quantum research to the European Union. Those motivations were: unlocking data protected through classical encryption via quantum computation, securing confidential information through quantum encryption, and the potential to grow a market for local players in the quantum space. With applications for quantum technology ranging from biological and medical research, to defence and computing, the Ministry concluded that it would be strategic to focus on the sector in coming years (Ministerie van Economische Zaken, 2015). Later that year, a market analysis by McKinsey confirmed this when the company announced that the worldwide quantum sector included ~7,000 people working on a combined budget of €1.5 billion (Palmer, 2017). Around the same time as this report, multiple nations began high profile projects intended to capitalise on their strengths in preparation for the forthcoming 'quantum economy.'

This analysis interrogates the underlying assumptions and explicit goals of this emerging sector through the lens of the sociotechnical imaginary, or a "collectively held, institutionally stabilised, and public performed [vision of a desirable future]" (Jasanoff & Kim, 2015, p. 4). Jasanoff and Kim posit that the sociotechnical imaginary originates in the visions of individuals or small groups. These visions become an imaginary by gaining traction through "blatant exercises of power or sustained acts of coalition building" (ibid, p. 4). In this case study, I argue that in 2013 through to 2018 we witnessed coalition building for quantum technologies in the United Kingdom, Canada, and the United States of America. Drawing on sociotechnical imaginaries also provides space for considering how processes of identity construction and visions of technological innovation are intertwined (Jasanoff &

Kim, 2009), and, consequently, how certain aspects of national identities filter through into national strategies.

Rhetorical analysis

The object of rhetorical analysis is not to categorise "persuasion for all times and all places" (Leach, 2011, p. 6). Instead, the power of this type of analysis is in "its immediacy, its ability to talk about the particular and the possible" (ibid). Rhetorical analysis is used for deconstructing arguments. It can be concerned with how arguments are tailored to publics and used to persuade or secure their support (Crawford, Breheny, Mansvelt, & Hill, 2019; Johnson, 2012; Santti, Puustinen, & Salminen, 2018). The rhetorical analyst looks at situated meaning production and interpretation of texts and seeks to map the ways in which a discourse responds to and influences events (Ploeger, 2002). Context of the discourse at hand was important (Leach, 2011). This chapter captures a snapshot in time in the evolution of three national quantum strategies and so required reflection on the place and time from which the rhetoric was emerging. The arguments put forward within each strategy were then considered in light of this context.

Rhetoric provides insight into the complex relationships between taxpayers, government, and publicly funded research (Ploeger, 2009). The analysis of the arguments put forward through these strategies for substantial investment of resources in the field of quantum physics drew on themes previously identified by Ploeger in her study of Fermilab, a high-energy particle physics lab in the United States (2009). Ploeger analysed a wide range of texts – including imagery and narratives – while interrogating the rhetoric that supports Fermilab's identity. This identity was vital to those science and technology actors who worked "to convince outside audiences of the necessity of these machines and those yet to come" (Ploeger, 2009, p. 83). In her study of Fermilab, Ploeger identified four central rhetorical themes: frontier mythology, the technological sublime, competition, and economic power.

Frontier mythology was first invoked and expounded upon by Vannevar Bush in his 1944 correspondence with then US President Roosevelt about post-war science. This theme drew on the notion of the United State's pioneer spirit and placed science as an unexplored hinterland with the potential for great rewards. In this setting, scientific progress was positioned as "key to security as a nation, to our better health, to more jobs, to higher standards of living, to cultural progress" (Greenberg, 2001, p. 57). The technological

sublime, on the other hand, is defined by Nye as "an essentially religious feeling, aroused by confrontation with impressive objects such as Niagra Falls… or the earth-shaking launch of a space shuttle" (Nye, 1996, p. xiii). Nye and Ploeger present this feeling of the sublime as an essential aspect of modern life that has the power to "weld society together" in the force of something "bigger than themselves" while putting the actions of the individuals at the centre (Ploeger, 2009, p. 56). The competition and economic power themes are outlined by Ploeger and also by Nisbet and Scheufele (2009). The competition theme deals with a game or race between groups; it deals with who is ahead or behind, who is winning or losing. Meanwhile, the economic theme reflects on development and competitiveness. The basic contention of this theme is that basic research drives economic growth and extends to market benefits or risks, and can be on a local, national, or global scale.

Of the possible four themes, economic gain and competition are routinely emphasised in the national strategies reviewed here. Each document in some way references the nation's need to be at the forefront of the field in both technological development and in reaping economic rewards. Meanwhile, the discourse of 'winning' the quantum technology race is one that is increasingly present in both the strategies and in media coverage. The way these themes are imagined for each nation is laid out below.

Interviews

In addition to the documentation already described, interviews were conducted with four quantum physicists who were involved with one or more of the visions articulated through the strategies. In contrast to the 'finished' products presented within the documents, these interviewees provided insider perspectives on the strategies. The interviews were semi-structured conversations centred around three key themes. Those themes investigated: how the strategies had come about; the role visions of the future play in advancing science and technology; and their perspectives on hype. The interviewees were elite framers (Jacoby, 2000), which meant their responses were not governed by general views on national strategies for quantum but instead gave specific insight into how and why the strategies were developed.

Interviewing helps "confront both meaning production and meaning produced" (Ploeger, 2009, p. 52). The interviews conducted for this case study generated stories about the way the national strategies came about in different national contexts. As Ploeger notes,

interviewing helps "engage respondents in a focused, but reflective, conversation" (ibid). Here, conversation provided an opportunity to deconstruct high-level rhetoric as well as insight into individual perspectives on the place of quantum physics and quantum technologies in futures to come. In other words, the interviews were acted as an avenue for further interrogation of the rhetorical texts analysed.

Interviewees were recruited by email. The ethical aspects of this research were approved by the Australian National University Human Research Ethics Committee (Protocol 2018/703).

Rhetorical analysis: Key themes in quantum strategies

Economic gain

In 2013, the United Kingdom's Defence Science and Technology Laboratory was the chief instigator of a meeting at Chicheley Hall between academic, industry, and government stakeholders where they reviewed the state of quantum developments. This meeting, and follow-up via a landscape report, communicated a consensus that the science was ready to produce real, workable technologies and that a quantum industry could soon be established. A subsequent bid to the government led to a £270 million initiative to set up the UK National Quantum Technologies programme. The UK National Quantum Technologies programme aims to make the United Kingdom a 'go-to' place for the development and commercialisation of quantum technologies and a leading player in the quantum global supply chain. One of the aims of the programme is to create a coherent quantum technology community from key stakeholders. It also emphasises "get[ting] quantum technology off the lab benches and into our hands to boost British business and make a real difference to our everyday lives" (UKNQT, 2015, p. 1).

The *2014 UK Quantum Technology Landscape* report, the first document produced after the Chicheley meeting, identifies promising focus points for development and investment (Pritchard & Till, 2014). Quantum here is the basis of a new, game-changing technology that represents the very best and latest scientific and technical development. For the United Kingdom, the technology has the potential to yield "immense economic benefit" and has near term applications in defence and security in addition to vast opportunities for long-term spin-offs (Pritchard & Till, 2014, p. 83). This messaging is continued in the revised landscape report in 2016 which contends that "to realise the

benefit of quantum technologies, [the United Kingdom] must succeed in converting its world-leading research into innovative and marketable products" (Till & Pritchard, 2016, p. 15). The strategy is meant to achieve "wealth creation on a multi-billion-pound scale within 10-20 years" by industrialising quantum technologies. Indeed a 2017 briefing on quantum technologies for the Houses of Parliament extends on this vague promise of wealth creation by outlining the estimated economic impact of industrialised quantum technologies, which could "become comparable in size to the consumer electronics sector" (UK, 2017, p. 1).

In Canada, the government has invested in quantum-centric research and development over the past decade. To capitalise on this investment and create coherence among the country's "vibrant quantum ecosystem", the National Research Council has launched the *Quantum Canada* initiative (NRC, 2018, para. 4). With an overarching aim of crafting a cohesive and visible focus for Canada's national interests in quantum, the strategy is meant to maintain and expand upon Canada's current quantum activity and to ensure that this activity delivers long-term prosperity (NRC, 2017). In pursuit of those goals, the National Research Council ran several engagement activities within the quantum community, including a national survey with over 350 respondents and a two-day symposium and workshop. A report issued following these activities included a call from the Canadian Minister of Innovation, Science, and Economic Development to "set big horizon goals and create broad-based partnerships to fund ambitious research projects that solve complex, large-scale problems and spark commercial opportunities" (NRC, 2017, p. 4). The National Research Council argues that the quantum industry will "create jobs and industries that never existed before, while reinvigorating established industries" and that Canada is in a strong position to achieve technology and economic 'wins' (NRC, 2017, p. 4). A report on these 'wins' – or the potential economic impact of quantum technologies in Canada – anticipated "massive impact in the next 5-25 years" and concluded that:

> "[It is] projected that by 2030, Canada will be able to grow an $8.2 billion quantum tech industry, employed 16,000 people and generating $3.5 billion in returns for the government…By 2040, quantum tech expected to reach 50% adoption, could grow into a $142.4 billion industry, creating 229,000 jobs and generating $55 billion in government returns" (NRC, 2018, para. 6).

As part of this process of engaging industry, the National Research Council ran a half-day workshop with the mining sector to examine how quantum technology can meet the needs

of that sector. The participants, both researchers and members of industry, were positive after discussions at the workshop and intended to continue collaborating and feeding ideas in the emerging national strategy.

Economic competitiveness in future product markets and stimulating new and current industries are driving forces for both the United Kingdom and Canada. The visions of economic gains developed in these strategies seems shaped by awareness of global activity in quantum. As in Burri's analysis of nanotechnology visions for Germany, the world here is "imagined as a place in which nations and regions compete for jobs, products, and markets" with technological innovation advancing individual nations and driving economic benefits (2015, p. 236). The potential for economic 'wins' also shapes the messaging used in the United States where lobbying for a national quantum initiative began visibly in 2016. That year saw the publication of a brief on *Advancing Quantum Information Science: National Challenges and Opportunities* by the US Committee on Science, the US Committee on Homeland and National Security, and the National Science and Technology Committee (USA, 2016). The document begins by providing background on quantum science and arguing that "recent advances have increased interest and motivated new activity both domestically and internationally" (USA, 2016, p. ii). With the "potential for substantial economic consequences" meriting special attention, the brief "outlines a federal approach for going forward" and suggests that quantum be a priority for federal coordination and investment as an "important component of US scientific leadership, national security, and economic competitiveness" (ibid, p. ii).

Preserving the leadership of the United States is seen to be a core concern in the lobbying for a national quantum strategy with warnings that "although the United States retains global leadership in the theoretical physics that underpins quantum computing and related technologies, we may be slipping behind others in developing the quantum applications" (Smith, 2017, para. 4). The need for the United States to remain at the forefront of technoscientific advances by developing quantum-based technologies is a priority that aligns with past messaging for national programs where science is "a resource to achieve and consolidate the global leadership of the United States" for research and in economic competitiveness, as well as in geopolitical terms (Burri, 2015, p. 238). This messaging extends further into a preoccupation with identifying emerging "threats" to the nation's safety and security.

Competitors and threats

When the *UK National Strategy for Quantum Technologies* was released (EPSRC, 2015), the vision and strategy encapsulated in this document framed quantum technologies in terms of future commercialisation. In this strategy, the United Kingdom is presented as a world leader and a major investor in the next generation of "breathtakingly powerful medical imaging devices to entirely new methods of computing to solve currently intractable problems" (ibid, p. 4). The strategy aims to protect the United Kingdom's stake in this burgeoning market. Its purpose is to preserve the nation's competitiveness on a global scale. As the writers of the document note: "failure to invest would mean failing to capitalise on the UK's strengths, leaving it trailing other countries" (ibid, p. 3). Following on from this, the *Roadmap for Quantum Technologies in the UK* was produced for stakeholders with interest in the emerging industry (EPSRC, 2015). The report highlights where new applications overlap with the interests of current companies. The roadmap echoes the positioning where United Kingdom is "ideally placed to be a world leader" as one of the world's major investors in the growing quantum industry. Building on the competitive narrative, the writers also acknowledge that "the UK is not alone in recognising the potential value of quantum technologies" (ibid, p. 24). Quantum continues to be represented as something that will "change our lives profoundly" and "affect the biggest markets" including finance, defence, aerospace, energy, and telecommunications (ibid, p. 5). Similarly, the *2016 UK Quantum Technology Landscape* presents a vision for the United Kingdom where "it becomes the world leading and world-renowned centre leading the second quantum revolution" (Till & Pritchard, 2016, p. 12)

A second report in 2016, issued by the UK Government Office for Science and titled *The Quantum Age: Technological opportunities*, forecasts the impact of quantum technologies with recommendations for the national programme and more wide-reaching initiatives (UK, 2016). This report reinforces the position of the United Kingdom as "at the forefront of a new era of quantum technologies" while laying out timelines for specific quantum technologies along with forecasts for various industries (ibid, p. 5). The quantum strategy in this report represents a "bold and confident claim to the future" which comes at a critical time to "capitalise on [the UK's] comparative advantage" (ibid, p. 5). Meanwhile a 2017 briefing on quantum technologies for the Houses of Parliament highlights that "there

is a strong case for continuing the National Programme in order to maintain the UK's global position" (UK, 2017, p. 4).

Messaging around *Quantum Canada* also stresses the importance of maintaining leadership in the quantum space (NRC, 2018). One of the first public signs of the national focus on quantum came in the form of a press release issued by the Perimeter Institute for Theoretical Physics (O'Flynn, 2016). Entitled *Quantum technologies a national priority for Canada*, the release focused on the Canadian delegation at the international Quantum Europe 2016 conference. Looking to the "second quantum revolution" and a new global industry based on new transformative quantum technology, the press release highlighted the 16-year investment by national and local government (ibid, para. 3). This effort was geared towards helping Canada to participate in the emerging industry and to establish the nation as a "leading global centre in [the] new large-scale exciting industry" (ibid, para. 8). In the same year, the National Research Council published a *Quantum Canada* page on their website that defined the quantum ecosystem in Canada and made a case for creating a national strategy (NRC, 2018). With the "world economy is being driven by emergent global trends" in technology (ibid, para. 1) and with quantum-enhanced technology nearing the point where it could disrupt and replace current technology, this is the time to provide a "visible focus for Canada's national interests in quantum and ensure the present-day advantage… [is] maintained and expanded for long-term economic prosperity" (ibid, para. 6). Canada is considered to be "well-positioned to become a global leader in the future quantum industry" (ibid, para. 2).

In 2017, the National Research Council published the results of a survey which canvassed information on quantum research and industry collaboration from academic researchers (NRC, 2017). Canada has invested over one billion dollars in the sector over the past decade and is considered here to be a "global leader in the emerging field" (ibid, p. 3). The survey results identified funding as a priority for researchers and suggested various weaknesses such as limited engagement with industry, a lack of national focus, and no long-term vision. With apparent urgency as "other countries [are] already executing their national quantum strategies", the survey results were meant to inform a "national initiative to grow coherence in Canada's vibrant quantum ecosystem" (ibid, p. 3).

Later that year, the National Research Council, the Natural Sciences and Engineering Research Council, and the Canadian Institute for Advanced Research held a symposium as

part of the effort to "support and grow a vibrant, coherent, globally competitive Canadian quantum ecosystem" (NRC, 2017). The symposium report details how Canada can "build of its strengths in quantum science and chart a path towards global leadership" (ibid, p. 1). The report emphasises the increasing competition in the quantum space arguing that "governments are recognising the massive opportunities in emerging quantum tech… [and] Canada cannot afford to stand still" (ibid, p. 8) and suggests that the "window for taking advantage of the opportunity is within the next one or two years" (ibid, p. 4).

Meanwhile, the landscape report on the quantum economy highlighted the global competition facing participants in the sector with:

> "Scientists and engineers across the world, increasingly funded by national strategies, … racing to develop technologies that can deliver incredible capabilities which will far exceed those of conventional technologies" (NRC, 2018, para. 1).

The National Research Council goes on to argue that Canada has a "unique opportunity to merge its position as a global leader in quantum science excellence with one of technology leadership" (ibid, para. 2).

In an example of the world-making effect of sociotechnical imaginaries, Miller writes that "globalism has been coproduced with novel technological systems… including technologies of observation, computation, visualisation, communications and transportation" (2015, p. 279). These technologies have enabled powerful advances in defence, travel, and how we communicate with distant places and events. While the competition to produce a new set of technologies to advance these capabilities is framed for the United Kingdom and Canada in terms of establishing leadership and in preserving a concentration of research and engineering talent, the United States appears to consider this competition in a different light by expanding the discussion to include potential crises of security and safety. Two bills on quantum technologies were presented to Congress in 2018, which separately call for a National Quantum Initiative and a defence-focused Quantum Information Consortium (USA, 2018, 2018). These bills follow on from lobbying by researchers and industry. In one instance, the National Photonics Initiative argued that quantum technology "jeopardizes the safety and security of the American people and threatens what has become the backbone of US economic growth" (2017, p. 1) when many nations are investing heavily, and the US has not capitalised on the available opportunities as the research moves from the lab to the marketplace. The threat of falling behind and

losing the chance at global leadership is consistently mentioned in similar calls for a national quantum strategy in media.

In 2017, testimonies were provided by experts in quantum to a subcommittee of the US House Science, Space, and Technology committee during a hearing on *American Leadership in Quantum Technology*. After highlighting national programs overseas, these experts argued that the United States risked 'falling behind' in the quantum race. As Chairwoman Barbara Comstock acknowledged in her opening statement, "American leadership in Quantum Technology is important to our national security, global competitiveness, and technological innovation" (*Statement from Chairwoman Barbara Comstock*, 2017). In a similar fashion to the UK National Quantum Strategy and Quantum Canada, the United States experts called for more focus and investment in the quantum space and framed their call within a broad nationalistic theme that aims to place each nation at the forefront of the emerging economy. Indeed, IBM's Scott Crowder testified that:

> "There is too much at stake to allow this country to fall behind. Our nation stands to benefit from quantum computers in ways we can't even imagine right now. The federal government should do everything in its power to ensure that we continue to lead the way towards a quantum future" (*Testimony of Scott Crowder*, 2017, p. 7).

Each testimony was framed in terms of the threat of other nations and provided a call to action to protect US competitiveness and national security. The concerns raised ranged from losing ground in defence-related technology to losing reputation and economic investment with Carl J Williams of the US Department of Commerce stating that, "While the US has made significant breakthroughs, the rest of the world has not been standing still – and US companies are taking notice" (*Testimony by Carl J Williams*, 2017, p. 3).

An arms race or a fun-run?

The rhetoric of these national strategies for quantum technologies and science can contrast sharply with accounts provided from individual physicists. An example of this occurred at a conference I attended during the write-up of this case study. The conference, *Project Q*, was focused on the political implications of the 'quantum race' at the start of 2019. Talks from researchers in the political sciences were heard throughout two days. In addition, a panel of quantum physicists spoke on the nature of their day-to-day research. The language used

during this conference to describe quantum research and development across the globe ranged from a 'quantum arms race' to a 'quantum fun-run', a 'friendly competition' and 'ultra-marathon' with a yet unidentified finish line.

Physicists at the event contested the framing of quantum technologies as precepting a possible 'quantum Pearl Harbour' by emphasising their work as "driven by goals of improving the society we live in" and "trying to solve problems in health, energy, [and] climate change". Adopting a more constructivist approach to quantum technology development, they described quantum as less revolutionary-focused and more akin to the birth of modern computing, progressing gradually from uses in defence to basic infrastructure at universities and on again to more pervasive use in society at large.

Separately to this conference, I conducted interviews to illuminate the events and decisions that led up to the creation of the national strategies analysed in this case study. Interviewees displayed an awareness of the lobbying and providing a clear vision to stakeholders with one individual noting that:

> "one of the challenges we face is that we need to get resources to do the kind of things we think are important, that have value, that stimulate people. Getting that resource requires an element of lobbying" (*Senior quantum physicist & government advisor*).

This lobbying required a clear understanding of the requirements of policymakers and politicians, and the ability to draw out clear benefits which creating a strategy would deliver.

For researchers working in Europe, creating the platform for the European Commission Quantum Flagship (launched in late 2018) required a demonstration that the Commission would be investing a future that would create jobs and be useful. One interviewee said: "… for the Commission they want to know that they're investing for the future – that the investment will create jobs and be useful" (*Quantum physicist & engineer*). Meanwhile, policymakers in the United Kingdom needed to see that there would be short term and long-term economic benefit, and the ability to generate a technologically educated workforce (*Senior quantum physicist & government advisor*). In the United Kingdom, crucial interactions with decisionmakers happened through "accidental connectivity" in a discussion on financial trade in which physicists were able to provide a solution to the need for time stamping in financial trade (*Senior quantum physicist & government advisor*). This proof-of-concept provided decisionmakers with an advisor on

quantum science and quantum technologies as interest and industry investment in the field began to rise.

The nationalistic focus was not present in their accounts of the strategies, although one interviewee did believe that the element of competition was a strong focus for the United States and United Kingdom (*Senior quantum physicist B*). They often chose to focus instead on the importance of community-building and creating critical mass to enable prototypes, commercially viable quantum technologies, and to support the development of a quantum technology-focused industry (*Senior quantum physicist & government advisor*, Quantum physicist and engineer). One interviewee did note that cybersecurity was a driving factor as "governments are acutely aware of the fact that they are behind the curve on this stuff" (*Senior quantum physicist A*).

Interviewees for this case study generally credited the sudden focus of attention from 2014 onwards to realisation of a crucial piece of the puzzle, "an error threshold that needed to be overcome and that threshold was accomplished by physicists… about three years ago" (*Senior quantum physicist & government advisor*). Subsequently, there were "investments on the order of billions by nation-states and corporate entities" (*Senior quantum physicist B*). The rapid adoption of national strategies to coordinate developments in quantum technology was seen to be a response to increasing investment by other nation-states and private companies. One interviewee said: "I think the investments on the order of billions by nation-states and corporate entities has suddenly focused attention in a way that it hasn't before" (*Senior quantum physicist B*). Where "initially it was all quantum theory driven by security applications" (*Senior quantum physicist A*) in the 1990s and early 2000s, serious money began to be contributed by industry some "three or four years ago" following a foundational achievement in relation to "how to generate stable results with the right fidelity, [or] the ability to deliver something with the right quality so it didn't make errors." When this threshold was accomplished, it suddenly made the long-prospected technologies feasible (*Senior quantum physicist & government advisor*).

These accounts contrast to with the idea that "quantum computing has become the new 'race to the moon' pursued with national pride and tremendous investments" (Moller & Vuik, 2017) and, instead, reflects on the continuing high levels of uncertainty around the eventual applications for quantum science. Ultimately, at this early stage it is difficult to say for certain whether doomsday predictions of a Quantum Pearl Harbour or more mundane

anticipations of incremental improvements to current technologies are correct. These alternately fearful and hopeful expectations for quantum technologies will both influence how social facts on quantum circulate in public dialogues (Borup et al, 2006; Durkheim, 1988). The presupposition of these futures implies that something in the future will bring them to life (Schyfter and Calvert, 2015). In Mackenzie's 'trough of uncertainty' expressions of uncertainty are highest among those closest to the field (MacKenzie, 1998). Right now, the alternate and more mundane rhetoric put forward by researchers in the interviews may in fact be part of attempts to influence narratives, modulate expectations, and prevent extreme disappointment (Eames, et al, 2006) in preparation for a potential situation in which the more revolutionary aspects of quantum technologies do not come to fruition.

Publics engaging in the quantum race

Although these strategies were developed within the space of a few years of one another, the potential for publics to engage with the emerging technology are markedly different. Responsible Research and Innovation is the key to how citizens of the United Kingdom are imagined in relation to the *UK National Strategy for Quantum Technologies*. Within the strategy itself is an explicit goal to create the "right social and regulatory context" for the emerging technology (EPSRC, 2014, p. 4). An interviewee who was strongly involved in the creation of the UK national strategy agreed that "public dialogue is absolutely essential, as we are spending public money and some of the things we do have immediate impact on the lives of the general public" (*Senior quantum physicist & government advisor*). Another interviewee noted that "the public are funding it, so they have a right to know. And some of the scientists' don't think about the general social implications of what they're doing… somebody has to give a thought to the public" (*Senior quantum physicist A*). However, while the United Kingdom approach emphasises inclusivity and co-creation of technology, it "largely fails to define tangible measures for the implementation of such a process" (Coenen & Grunwald, 2017, p. 282).

Quantum technologies are framed as "perhaps the greatest disruptive innovation for which Canada has an opportunity to lead globally" in the 2017 symposium report (NRC, 2017, p. 10). Despite, or perhaps because, of this anticipation of considerable impact for the nation, there has been no real mention engaging citizens outside of industry and government within the technology and emerging national strategy. While the symposium

report includes recommendations for "diverse forums to promote broader understanding of potential impacts of quantum", these forums are restricted to users and sectors – largely from industry (ibid, p. 10). The sole mention of dialogue in the report is made in the context of setting up an industry network to increase engagement with new applications. More broadly, in the documents examined from the start of *Quantum Canada*'s emergence, understanding is referred to in the context of scientists working with key stakeholders in industry and government. The only reference to communication beyond these stakeholders is made in a survey response where a federal researcher argues for "more publics relations for scientists and their work in Canada... [and] stronger advertising and showcasing of Canada's quantum science agenda" (NRC, 2017, p. 8). Similarly to Canada, the United States' bill that outlines the *National Quantum Initiativ*e places citizens in a distinctly linear relationship with advocates for the technology and refers to public outreach in the sense of "dissemination of findings and recommendations… as appropriate" (USA, 2018, p. 7). While these are early days for this strategy, it appears that the involvement of citizens in the United States has been imagined in a similar sense to the relationship depicted in the US National Nanotechnology Initiative where outreach activities aimed to foster citizens understanding and acceptance of the technology (Selin & Boradkar, 2010).

Interviewees commenting on the communication of quantum technology more broadly reported that "public outreach [was] starting to increase" and that researchers were discussing how to "convey that ideas in quantum physics can be useful for a 'normal person'" (*Quantum physicist & engineer*). Another commented that they had been shocked at a recent public talk when an audience member asked whether quantum technology meant that they were going to lose their privacy (*Senior quantum physicist B*). On this subject, the interviewee remarked that this question meant that "[we've done a] terrible job of explaining what it [quantum technology] means" (*Senior quantum physicist B*). Quantum technologies differ from other emergent, new technologies in the sense that citizens are positioned as downstream consumers. This places citizens in the position of supporting the research without dialogue around societal implications of the technology until late stage applications, if at all. Instead, the nature of quantum technology means that the end-users at this point are various industry sectors, including finance, telecommunications, defence, and mining. For the United Kingdom, industry was one of three sectors present from the first meeting in Chicheley Hall to lay out the path of the national strategy (*Senior quantum*

physicist & government advisor) (EPSRC, 2014). As a group, industry has been consistently placed alongside academic in all documents issued by the government. They are key partners delivering on the goals of the strategy and are consequently integrant to the success of the emerging quantum economy. In some ways, Canada has paralleled this activity with industry and government clearly identified as key stakeholders who must be engaged to deliver a "cohesive vision for Canada's national interests in a quantum" (NRC, 2017, p. 3). The relationship here with industry has taken on a more structured form with specific forums established for specific users and sectors to identify where quantum technologies might be able to meet industry needs. Within the United States, industry appears to have taken this active role a step further in establishing a lobbying group – the *Quantum Coalition* – that is comprised of key companies in the space. They have championed the messages that frame quantum technologies, specifically concentrating on quantum computing, as a geopolitical competition and a problem for national security if America does not defend its technological leadership (Gregg, 2018). This group has also made clear their goal of pushing the new legislation for the initiative in two directions: first, an increased focus on applied research, and second, support for workforce development.

At the Project Q conference, the predominant theme of discussion was concern over concentration of knowledge and power through quantum technologies. While these concerns appear hyperbolic in and of themselves, answering them is not a matter of simply ensuring that the relevant "scientific knowledge … be made publicly available as much as possible, and quantum computing power should be made accessible through the cloud" (de Wolf, 2017, p. 275). One researcher pointed out in a special issue on ethics and quantum technology, "the quantum technology initiative(s) gives them [researchers] cover, so to speak, in order to continue doing what they like" (DiVincenzo, 2017, p. 250). With the number of national strategies for quantum and investments in the field increasing, there is a need to discuss the "impacts in a societal debate on quantum technologies" (Vermaas, 2017, p. 246). In doing so, this debate could seek to elucidate both the proposed benefits and risks of quantum technology, outline the continuing uncertainty around the ultimate forms (and deadlines for creation) of these technologies, and frame a role of co-production for citizens as well as industry players.

Conclusion: Power in the quantum age

Sociotechnical imaginaries help us understand the "messy, long-term processes through which national technopolitical identities are created and maintained through the uptake of technological developments" (Felt, 2015, p. 104). In the *Dreamscapes of Modernity*, Jasanoff and Kim (2015) based their concept of sociotechnical imaginaries on the intertwined relationship of the social and the technical. Their framework draws together the scientific and cultural perceptions of reality and shows how we create new collectives through technological *and* social means (ibid, p. 14). In the case of technological revolution, it is tempting to put the science and technology at the heart of the issue – in this case, the emerging quantum economy might seem inevitable in the face of the purely technological advantages of the science. However, social change is necessary for any kind of technology revolution. In this case, different social factors are at work which shape each nation's approach to achieving leadership in the 'quantum race'. This is the crux of the world-making aspect of the sociotechnical imaginary.

In the *UK National Quantum Strategy*, quantum technologies are positioned as potentially contributing to national economic growth through innovation. By investing in this field, the government aims to preserve the nation's competitiveness in the future product market and drive the development of a skilled labour force. This preoccupation with economic success and maintaining a competitive edge is offset by acknowledging the necessity of developing the 'right' social and regulatory framework for the technology. The foundation of this framework includes a Responsible Research and Innovation-based dialogue with multiple stakeholders and has resulted in the first report on public perspectives on quantum technologies. In the meantime, the messaging for the emerging *Quantum Canada* strategy echoes much of the language used throughout the *UK National Quantum Strategy*. Here, quantum technology plays a central role in advancing the economy and time to translation is presented as decreasing. While multiple stakeholders have been consulted within industry, academia, and government, the advocates for the strategy have not yet expressly consulted with wider public groups. The rhetoric surrounding the emerging *National Quantum Initiative* in the United States is the most markedly different of the three strategies with framing extending from enabling economic gain and providing a competitive edge to issues of security and safety. Perhaps some of the differences here can be attributed to the great role taken by industry in lobbying for a

national quantum agenda with the corporate-formed *Quantum Coalition* acting as one of two main advocacy groups.

The strategies in each of these three national settings frame expectations for quantum not just in a sense of the technical advances the field may achieve but also in terms of motivations for investing in a long-term, cohesive national agenda. The lobbying to produce these strategies highlights the potential for economic gain, the need to maintain global leadership, and, for the United States, security concerns. In doing so, they have shaped national strategies and perhaps even the technology itself.

Here, hype has helped to mobilise, legitimate, and coordinate concrete activities in the name of creating a quantum-based industry. The revolutionary rhetoric used to frame a still young and esoteric raft of new technologies has been both strategic and performative. The futures imagined in this case study frame how the future 'should' be and may, in doing so, make those futures real. They have certainly shaped the way society is going to start making sense of quantum technologies by packing up a world that desired and can use them. This account of hype reinforces that science and technology development is rarely linear or deterministic with complex factors at work that influence whether a technological pathway is adopted and followed through. In the following chapter, I consider how complex factors – such as a demand for societally relevant research – influence the development of research agendas for science and technology.

Chapter five: Grand Challenges for research

> *"The future we're imagining. That's what we're hoping for." (Obama, 2013, para. 13)*

> *"If we wait for the future to become the past, we leave the design of the future to others" (Fujimura, 2003, p. 192)*

In the twentieth century, a photo snapped by astronaut William Anders during the Apollo missions played a pivotal role in the growing wave of environmental consciousness. The image – Earthrise – presented the Earth as a fragile blue sphere, suspended in the void of space. In an interrogation of how this image influenced collective understanding of humankind's place in space and the fragility of the Earth's environment, Jasanoff asks: "What makes people from different societies and cultures believe that they should act to further common goals, even if these goals require them to sacrifice or postpone perceived economic and social interests?" (Jasanoff, 2001, p. 4). In Chapter 5, I consider a similar question: how do research funders commit to collective action at a global scale in the pursuit of a 'big idea' or common cause? And, more specifically, how does this commitment translate to research agendas?

Linguistics researcher Norrick (2004) frames hype as tending towards metaphoric and imagistic expressions. The case of hype analysed in this chapter serves as a good example of this as the language used is urgent but optimistic, and frames research through global problems such as climate change, and disease. Whereas the previous two case studies in Chapter 3 and 4 focused on imaginaries being created and driven by science and technology organisations and researchers, this chapter focuses on the agenda of research funders. Specifically, this case study is concerned with a mandate issued by research funders for research with societal relevance and impact.

Here, I describe the history of grand challenges in science policy and consider the influence of a growing shift towards anticipatory governance and science done 'for and with' society. This history and literature forms the background for my analytical approach in this case study, which I then outline. After this, I compare claims made for three grand challenge programs. Crucially, these examples allow for a comparison between the claims of

societal impact between three programs which – although different in origin and design – evoke the same grand challenge approach. They also enable reflection on how the use of grand challenges draws on the historical legacy of the term. In this chapter, I use an epideictic rhetoric framework to analyse the arguments that motivate grand challenges for research and position science and technology as the solution to global problems. Historically explicitly associated with hype (Ritter, 2010), epideictic rhetoric acts as an invitation for participation and engagement. It also provides "a means for envisioning and urging changes for the better" (Sheard, 1996, p. 788) and invites critical thinking. In the grand challenges case study, this genre of rhetoric enables my analysis of how arguments were presented which aligned research programs with public values to build support and consensus.

Grand challenges – also known as 'Grand Societal Challenges', 'Societal Challenges', and 'Global Challenges' – represent a dominant trend in research funding programs. The concept began within science policy, funding, and research circles and has begun to creep into media coverage and some wider public dialogue (Flink & Kaldewey, 2018; Reddy, 1988; Wissenschaftsrat, 2015). In the past two decades, grand challenges have shifted to increasingly address 'grand', 'societal', and 'big' problems (Kaldewey, 2018). These grand challenges are intended to be more than routine questions or research priorities. They turn societal problems into scientific challenges and have an undeniable emotional and motivational component (Wissenschaftsrat, 2015). Grand challenges refer to a belief that science and technology can influence the global problems of our time (Miller, 2015). For science policy and research funders, grand challenges invoke ideas of strategic orientation and resource allocation with widespread and diverse examples ranging from 'moonshot' missions such as the Apollo and Manhattan projects to health- and robotics- focused programs. Across the varied fields and organisations that have adopted the grand challenge framework a common feature is the adoption of optimistic, sports-centric terms (Kaldewey, 2018). This language means that researchers are tackling problems and competing to solve them. The work itself is done in an atmosphere of apparent urgency and with the aim of contributing towards complex, difficult issues. Grand challenges often appear to be problem-centric, concerned with predominantly technoscientific solutions for an ever-widening array of issues.

An example of a grand challenge program – the BRAIN Initiative – was launched in the United States during 2013. At the launch, US President Barack Obama framed the focus

of the project (mapping the human brain) as a "mystery to be unlocked" and outlined an array of potential societal impacts:

> "Imagine if no family had to feel helpless watching a loved one disappear behind the mask of Parkinson's or struggle in the grip of epilepsy. Imagine if we could reverse traumatic brain injury or PTSD for our veterans who are coming home... What if computers could respond to our thoughts or our language barriers could come tumbling down" (Obama, 2013, para. 12).

This address bears witness to the increasingly central role played by science and technology in rhetoric of our daily lives (Fujimura, 2003; Jasanoff & Kim, 2009). Grand challenges underscore this role by positioning science and technology as essential ingredients of progress and vital steps on the road towards feasible, desirable futures. In doing so, they reflect an overt steering of science policy work so as to meet stated political goals (Cagnin, Amantidou, & Keenan, 2012).

The way research agendas, such as the BRAIN initiative and other grand challenges, are framed alters the way science and technology actors identify priorities and potential solutions. Research agendas are "an exercise in future thinking with the aim of identifying what is wanted (e.g. employment) and not wanted (e.g. pollution)" (Bina, Mateus, Pereira, & Caffa, 2017, p. 167). Grand challenges are meant to direct science, technology, and innovation policies while addressing multiple stakeholders and issues (Kuhlmann & Rip, 2014) and holding scientific enquiry accountable to society (Hackett, Parker, Vermeulen, & Penders, 2017, p. 745). In practice, they provide centralised funding and explicit project aims; they are a way to focus the attention of researchers from multiple disciplines, philanthropists, politicians, and wider publics (Hicks, 2016).

In a broader sense, these challenges provide a narrative for contemporary research, which might also be labelled the impact agenda or the drive to demonstrate societal benefit. It is here that hype, or future focused and sensational rhetoric, is adopted to position science and technology centre-stage within visions of future possibilities. This future-focused work is done by science and technology actors who craft expectations – through voicing promises or concerns – and is intended to influence how attention and support is directed to a particular area. Hype in this case study can potentially restrict possible solutions to global problems, but also provides a way to open up discussion for the co-creation of futures through a framework of anticipatory governance.

Looking to science policy: The origin of grand challenges

Imagination is a social practice deployed in the curation of desirable futures. This practice creates persuasive visions of potential futures and "is serious work done by serious people… [whose visions work has] enrolled and engaged many people, funds, and government agencies" (Fujimura, 2003, p. 192). It is not just scientists who engage in this practice; politicians, policy-makers, and funders are among the actors who work to create desirable futures based on technoscientific developments (Konrad et al., 2017). As discussed in Chapter 2, these actors strategically craft expectations for these futures, which may emerge as promises or concerns as they sketch out the potential benefits and problems that might follow on from, for example, investing in a field of research (te Kulve et al., 2013; van Lente, 1993). It is within this context that this chapter considers how funding agencies – both public and private – work towards specific futures through grand challenges for research.

The contemporary focus on grand challenges contrasts with what is known as the 'trickle-down' model of science, originally described by Vannevar Bush in *Science, the Endless Frontier* (1945). In this work, Bush argued that scientists should be left alone to determine the focus of their research (Frodeman, 2016). He wrote that so long as"scientists are free to pursue the truth wherever it may lead, there will be a flow of new scientific knowledge to those who can apply it to practical" (Bush, 1945, para. 58). Bush believed that scientific research should be untroubled by practical concerns and social imperatives as these would "only render the process more inefficient" when compared to curiosity-based research (Frodeman, 2016, p. 108). Support for this approach seems to have eroded over the last few decades as desire to see science and technology contribute to societal issues has come to the fore (Cagnin et al., 2012; Guston, 2012) with research efforts increasingly organised through grand challenges. In these grand challenges, a problem – which is classified as complex, urgent and in need of both political and financial support to generate solutions through research – becomes the focal point (Frodeman, 2016).

A list of unsolved problems created by mathematician David Hilbert is often mistakenly identified as the starting point for grand challenges (Brooks, Leach, Lucas, & Millstone, 2009; Gates Foundation, 2003). In fact, Hilbert's approach was representative of different a twentieth century focus for science and politics (Kaldewey, 2018). As Kaldewey (2018) points out, Hilbert's "conception of 'mathematical problems' differs considerable for

the twenty-first century notion of 'societal' or 'grand challenges'" (2018, p. 164). Specifically, this list of problems was designed to be reflective – in that Hilbert focused on the turn of the century as an appropriate time to look to the future of mathematics – and disciplinary, as he was primarily concerned with preserving the unity of the mathematics field. The problems Hilbert offered were intellectual and, consequentially, unconcerned with translation. They were "reassuring rather than energizing", designed so as to use the existence of the problems to claim that the field of mathematics had a future (Hicks, 2016, p. 29).

A more accurate starting point for grand challenges is the rise of science policy references to the term, which began in the United States during the 1980s with Kenneth G. Wilson's calls for federal funding of high-performance computing. This eventually resulted in the High-Performance Computing Act of 1991. For a full account of this advocacy, see Hicks (2016). In was at this time that Wilson adopted the then new term 'grand challenge' in an attempt to form a motivated community of advocates for theoretical computing. In 1987, Wilson explicitly used 'grand challenge' as a title of a talk where he noted: "The challenge is to move from the present situation, where there is plenty of research going on, to achieve the really spectacular discoveries which have not been made yet" (Wilson, 1988, p. 162). Two years later, he provided the rationale for the term 'grand challenge' by mentioning "the need for excitement as a component of efforts to win support and the difficulty of generating it in computing" (Hicks 2016). He writes that "key areas with both extreme difficulties and extraordinary rewards for success should be labelled as the "Grand Challenges of Computational Science" (Wilson, 1989, p. 172).

Ultimately, Wilson's advocacy was successful. His work laid the foundation of the US federal science policy discourse for high-performance computing and communications in the 1980s. This was followed by a strategy in 1991 which explicitly referenced specific grand challenges, including: forecasting severe weather, predicting new superconductors, and air pollution (Hicks 2016). Meanwhile, the High-Performance Computing Act defined grand challenges in United States legal code as:

> "… a fundamental problem in science or engineering, with broad economic and scientific impact, whose solution will require the application of high-performance computing resources and multidisciplinary teams of researchers" (Hicks, 2016, p. 27).

This was the beginning of the use of grand challenges within science policy. Then, in the 2000s, they began to be incorporated into research.

In 2003, grand challenges were recast to motivate international communities of scientists towards predefined goals by the Bill and Melinda Gates Foundation through their *Grand Challenges in Global Health* (Gates Foundation, 2003). At the time Gates said: "when scientists are given a chance to study questions that could save millions of lives, they eagerly rise to the challenge" (Gates Foundation, 2005, para. 8). The use of grand challenges here has been regarded as pioneering as it influenced the discourse for global health (Wissenschaftsrat, 2015), although this impact of the Foundation on the agenda for global health research has also led to critiques regarding transparency and accountability in decision-making (Ulnicane, 2016). Around the same time, a group of global health scientists identified and published "Grand Challenges in Chronic Non-Communicable Diseases" in *Nature*. These programs, along with similar schemes addressing 'grand', 'societal', or 'big' challenges, focused first on the biological and health sciences and then extended their scope to include additional disciplines (Efstathiou, 2016).

The increasing threat of climate change is another source of the grand challenges discourse (Wissenschaftsrat, 2015). In 2009, when the European Research Area (ERA) Board first referenced "an ERA driven by societal needs", they pointed out the grand challenges of "climate change, energy supply, water resources, ageing societies, [and] healthcare" (Wissenschaftsrat, 2015, p. 10). This was part of a wider shift to challenge-based research with mandated societal impact (Daimer, Hufnagl, & Warnke, 2012). This shift is exemplified by the European Commission's Lund Declaration, which announced that "Europe must focus on the Grand Challenges of our time" (Lund Declaration, 2009, p. 1). In part, a focus on grand societal challenges was chosen to position European research as solving issues faced by the global community. These challenges also positioned research and innovation as pivotal for continued economic growth and sustainable development for the region (Wissenschaftsrat, 2015). Grand challenges became the guiding framework for the European Commission's research program Horizon 2020 (Bina et al., 2017). Research councils in the United Kingdom followed this approach shortly after by adopting challenge-based funding schemes.

This shift towards the grand challenge approach was mirrored in the United States when the White House launched its 21st Century Grand Challenges program, which were

presented as “ambitious, achievable goals that harness science, technology, and innovation to solve important national or global problems” (Kalil, 2012, p. 1). As part of the launch, US President Obama called on multiple actors – including companies, research universities, foundations, and philanthropists – to help identify and pursue grand challenges. These grand challenges should in turn help create industries and jobs, expand the frontiers of knowledge, tackle important problems, and act as a ‘north star’ for public-private collaboration (Obama, 2013). Assistant-Director for Grand Challenges at the US Office for Science and Technology Policy Cristin Dorgelo described this focus as “setting moonshot goals so that cross-sector partnerships could set course for those ambitious goals and try to solve big problems” (Dorgelo, 2018, p. 4). Part of the appeal of these ‘ambitious goals’ is the strong link to societal impact as research funders draw a connection between basic research and improved products, treatments, and overall well-being.

Science as a social understanding

The meaning and motives that inform grand challenges have changed; they are no longer concerned with problems to be solved, instead they are focused on challenges to overcome. Early examples of grand challenges – for instance, the War on Cancer and the Japanese Challenge – drew on the metaphor of war and nationalist rhetoric to portray disease and other nationalities as the enemy. Now grand challenges are predominantly framed in positive rhetoric and are distanced from suffering and death. Through emphasis on elements like ‘create’, ‘design’, ‘prevent’ and ‘cure’, advocates avoid doubt over the likelihood of success and bypass the risks of new projects (Kaldewey, 2018). This language asks stakeholders to connect basic research to concrete outcomes. Rather than emphasising struggle and conflict, the language is entrepreneurial in nature with a focus on individual innovators producing tools and treatments.

Motives driving the rise of grand challenges for contemporary research seem to reflect a changing landscape for research in which increasingly complex science-society relationships mean that research has become a “social undertaking” (Bijker & d'Andrea, 2009, p. 1). As reviewed in Chapter 2, there has been a move away from evaluating research funding decisions and project outcomes purely in terms of excellence with a new, growing emphasis on societal relevance (Bos, Walhout, Peine, & van Lente, 2014; Felt, Igelsboeck, Schikowitz, & Voelker, 2013). One example of this change is the rise of responsible research

and innovation frameworks (Flink & Kaldewey, 2018). The push for responsible research and innovation is linked with a drive to increase the impact of science and science policy and to go beyond claims of economic value (Stilgoe & Guston, 2017). With the social impact of research pushed to the fore, researchers are increasingly expected to be accountable to, and open with, the citizens who fund their work and their research is expected to clearly contribute to societal priorities (Frodeman, 2016; Nerlich, Hartley, Raman, & Smith, 2018). This shift is happening as the nature of research projects also changes with projects growing larger – and more inclined towards collective enterprise – and complexity and cost also increases. In addition, there is a recurring focus on application, or on research with commercial outputs. These trends may mean that the focus on "social contextualisation" of research is more "undergone than desired" with researchers perceiving the requirements as a limitation rather than a motivation (Bijker & d'Andrea, 2009, p. 123).

Significant national and international programs, such as the European Horizon 2020 scheme, are focusing on grand societal challenges for research. These programs call for enhanced, transdisciplinary engagement between scientific and societal actors to assist in developing more robust solutions to societal challenges (Felt et al., 2016). These calls for engagement and impact are influenced by reflections over: who has the right to participate in defining research problems and developing solutions; who has the correct blend of knowledge and experience to identify and address those complex societal problems; and how to strengthen the credibility of science-driven solutions in the public domain (Felt et al., 2016; Parandian & Rip, 2013).

Despite these rather worthy motivations, grand challenges can appear more focused on technological ends than social solutions. Specifically, while grand challenges emphasise societal demands they lack adequate indicators to measure social impacts and are yet to incorporate members of society as innovation actors rather than simply consumers or end-users (Daimer et al., 2012). In a review of how philanthropists drive the development agenda, Brooks, Leach et al (2009) suggest that grand challenges draw heavily on the notion of a 'silver bullet', a phrase commonly used in science policy to refer to bolstering or undercutting claims made for technological breakthroughs. Silver bullet claims generally draw upon three key features: technical progress, generic application, and scalability. Many grand challenges retain and build upon these characteristics by emphasising the achievement of urgent goals through the rapid development of technologies. They also

retain a simplistic approach to the deployment of those technologies, often replicating – rather than challenging – existing power-knowledge relationships (Brooks et al., 2009). In this rush to provide a technological fix, reduced time and space for questioning answers to complex problems may in fact mean that the desired impact of grand challenges is not fulfilled.

To properly consider grand challenges as science policy interventions, the agenda for the challenges must be more than creating a technological fix. Grand challenges should serve to redirect "innovation activities along more sustainable pathways that enable positive transformations of socio-technical systems" (Cagnin et al., 2012, p. 141). In order for these challenges to become more than a technological fix, actors must also look to the broader changes required in "human perceptions and behaviour, as well as social innovations for promoting non-technological solutions" (Cagnin et al., 2012, p. 143).

Constructing imaginaries: Opening up futures (and closing them down)

Tapping into the grand challenge narrative is an act of agenda setting that determines the future direction and impacts of research. When an actor refers to a "problem area as a Grand Societal Challenge [it] corresponds to an act of setting societal and political priorities" (Wissenschaftsrat, 2015, p. 18). Grand challenges are designed to direct us towards some futures and away from others (Schyfter & Calvert, 2015). In other words, the framing of grand challenges largely determines how researchers search for answers and solutions because it affects what is prioritised for funding and implementation (Bina et al., 2017). Grand challenges on a whole: "Invoke and establish notions of human and social progress… As an approach they presuppose and reinforce the central role of science and technology in the shaping of societies of the future" (Bina et al., 2017, p. 167). As a result, we must clarify the existing and growing ideas that guide the creation and our understanding of these funding schemes.

Designing grand challenge programs is difficult. One criticism of existing schemes outlines how the growing profile of grand challenges has led to innovation and problem-solving gaining prominence (Efstathiou, 2016); this feature joins with the emphasis on a related concept: translation. The focus on translation "aims to capture and to channel the power of technoscientific knowledge in contexts of action or policy" (Klein, 2016, p. 107). This makes monitoring the design, influence, and impact of these programs critical (Cagnin

et al., 2012), particularly as scientific research alone cannot adequately address challenges faced by society (Efstathiou, 2016). In arguing this point, Efstathiou distinguishes between two uses of the grand challenge concept to refer to challenges of technical difficulty – or, grand-in-difficulty challenges – and challenges that must involve societal stakeholders so to improve the uptake of solutions – or, grand-in-scope challenges. Grand-in-difficulty challenges are more amendable to technical fixes than the grand-in-scope, while grand-in-scope challenges often necessitate multiple levels of action and are noticeably global, or 'everybody's problems' (Efstathiou, 2016). A similar distinction is made in the Horizon 2020 review on two types of mission-based policy: the technology accelerator and the societal transformer (EC, 2018). The case made here for two kinds of problems draws on Nelson's work (Nelson, 1977, 2011), which highlights the need for research to address major social concerns and considers the difference between solving technically complex issues (his archetypal example is the Apollo moon landing) and socially complex dilemmas (for example, widespread poverty).

One way to reintroduce and enforce the presence of the social in grand challenges may be to look at the challenges in terms of the sociotechnical imaginaries that underwrite them. In doing so, it is possible to reflect on the values and emotions linked with the challenges, and to also open up new ways of understanding (Jasanoff & Kim, 2015; Tutton, 2018). Grand challenges represent certain expectations for the way life could and should be lived, and for how science and technological research and development should bring about those desired states. Konrad et al. write that "expectations of scientific progress are enduring components of 'grand challenge' narratives, buttressing arguments about how science and technology are supposed to address the wicked problems of the twenty-first century" (2017, p. 465). These expectations can act as social facts that influence behaviour (Durkheim, 1988) and can be made visible through anticipatory practices, such as roadmapping or foresight exercises (Konrad et al., 2017).

Imaginaries can be used to highlight the shaping of expectations and visions by considering how future-oriented narratives open up some pathways while closing down others. As discussed in Chapter 2, sociotechnical imaginaries provide a holistic view of collectively imagined forms of social life and social order (Jasanoff & Kim, 2015). They present a view of the world that comes to shape agendas, research trajectories, projects, and policies (Smith, 2015). Imaginaries upon which projects and schemes rest can be

interrogated so as to consider how the values within them are embodied (or not) in research practice (Felt et al., 2016). In the rest of this chapter, imaginaries (and the expectations and visions that inform them) of three separate grand challenge-centric funding schemes will be reviewed and compared to consider how the schemes work to convene select futures.

Method: Grand challenges as technologies of anticipation

Anticipatory work opens up a space for furthering the democratisation of science and technology as it positions the future as an object of public imagination and, therefore, public dialogue and response. Grand challenges are designed to address 'everybody's problems' and to create 'better' (sustainable, inclusive, prosperous) futures. Their proponents work to determine the sort of future they desire and the future(s) they wish to avoid. This type of practice is an inescapable part of social life and "anticipation has become a common, lived affect-state of daily life, shaping regimes of self, health and spirituality" (Adams, Murphy, & Clarke, 2009, p. 247). An atmosphere of anticipation has led to an assumption that decision-makers, researchers, and even citizens have a moral responsibility to anticipate, or to be well-informed and ready for the future (Tutton, 2011). In this space, every future vision is founded on others that are to be avoided. Positive visions and optimism grow out of concerns for future risk (such as, events to be avoided) and pessimism around the potential social and ethical implications of new technology.

The notion of progress as we experience it today is wedded to a belief science and technology are the key to solving social problems (Konrad et al., 2017. There is a "palpable sense that things could be (all) right if we leverage new spaces of opportunity" and reconfigure what is possible (Adams et al, 2009, p. 246). Some of these expectations and visions for these solutions will inevitably underperform and may come at a price (Apreda et al., 2014; Arribas-Ayllon, Bartlett, & Featherstone, 2010). Despite this, "it remains difficult to see whether – this time – our high expectations might be justifiably warranted" (Borup et al., 2006, p. 290). Expectations play an evaluative role in this context by functioning as informal, de facto assessments of emerging technologies (Rip, 2010; te Kulve et al., 2013), which influence how science and technology are valued in a community and shape how people make sense of developments that are not yet concrete (Konrad et al., 2017).

As I have argued, grand challenges shape desirable futures by explicitly addressing how societies or groups can work towards 'better' futures. My approach in this case study is based on the idea that the rhetoric used to put forward the challenges also positions science and technology at the centre of these futures. Interrogating the rhetorical claims made for these programs is important as the framing of research funding schemes, policy, and project trajectories can influence allocation of public and private priorities and funding. Here, we now turn to the analysis of this chapter, which considers and compares the claims within the program documents of three grand challenge-based programs.

Argument analysis

My analytical approach is informed by research on epideictic rhetoric. Epideictic rhetoric works to reinforce adherence to commonly held values through the use of praise and blame. These dual techniques encourage celebration and criticism within largely homogenous cultures (Sullivan, 1993). For a postmodern society – made up of cultures with competing values and perspectives – the epideictic works to build consensus by identifying and bringing together the interests of individuals and communities (Condit, 2018; Sheard, 1996). In this contemporary capacity, "epideictic rhetoric also involves education, legitimation, and values intensification" (Tomlinson & Newman, 2018, p. 12). In the course of building consensus, the rhetor uses vivid language and attempts to enhance connections between audience, speaker, and content (Condit, 1985). To achieve this, epideictic discourse expresses and recreates a community's identity by "expressing and restructuring [a community's] symbolic repertoire around special events, places, persons or times" (Condit, 1985, p. 292). In this discourse of values, a model for "exemplary civic behaviour" is constructed and evokes a "collective recognition of shared social responsibilities" (Lauer, 2015, p. 10). Lauer notes that "at times, epideictic values are so strongly linked to functional deeds that advocating values becomes tantamount to advocating action" (2015, p. 16).

In this chapter, I conduct an argument analysis by examining the structure and claims that appeared throughout the grand challenge documentation. I present samples of these arguments in tables 1 and 2.In doing so, I adopt part of the approach used in Fahnestock's analysis of epideictic arguments in science where she outlines two basic appeals used to make science relevant to broader, non-specialised audiences (1986). The appeals are: the deontological argument ('the wonder') that attempts to praise a subject by

linking it to something that the audience values and the teleological argument ('the application') that claims something will lead to further benefits. In other words, a statement praising the space shuttle for 'never before' made achievements of humankind in space is an appeal to 'wonder', whereas an appeal to 'application' points out spin-off technologies from the space program. These appeals are characteristic of the epideictic genre of rhetoric. Rather than being concerned with the reporting of 'fact' as in forensic rhetoric, the epideictic is concerned with celebration. The appeals, as identified above, are explicit, even blatant, when describing the value of some scientific or technological development. At the time Fahnestock wrote their article, this style of rhetoric fell into the category of 'accommodation', what we might now more commonly consider to be popularisation. For this case study and research in hype more generally, these appeals help make visible implicit values associated with science and technology research.

The audience has a unique role in epideictic rhetoric. On the surface, audience members are passive, merely acting as observers. In reality, they have a much more complex and active role (Condit, 2018). "The audience judges the competence of the speaker to make judgements about the praiseworthy and blamable, and in turn, receives insight into those objects of praise" (Oravec, 1976, p. 172). In other words, the speaker makes representations to the audience and they, in turn, judge both the content of the speech and the speaker. In this way, epideictic rhetoric is a "rhetoric of opportunity and possibility that invites critical thinking" while being "capable of building 'community' in the postmodern era" (Sheard, 1996, p. 176). The audience's agency is enhanced by uncovering the ways in which power is asserted. This active audience role mirrors the hazards encountered when attempted to convene a public.

This responsive quality of epideictic rhetoric is mirrored in its reciprocal relationship with the world at large. The epideictic discourse "both responds to and creates 'opportune' and 'critical' moments in time that warrant attention and corrective action" (Sheard, 1996, p. 789). Fahnestock characterises this function further in stating that "people inevitably have to be convinced that a situation exists before they ask what caused it or move on to decisions about whether the situation is good or bad and what should be done about it and by whom" (Fahnestock, 1986, p. 290). Epideictic rhetoric is this sense has both performative and preparatory roles in catalysing or positioning an issue even while emphasising values that "might later support legislative and judicial arguments" (Condit, 1985, p. 297).

Importantly, epideictic rhetoric works "not only to maintain community values… but also to accomplish the progressive function of adapting our community to new times, technologies, geographies, and events" (ibid). This almost conflicting role of influencing and drawing on community values is of interest to my analysis of the grand challenge programs outlined below. Primarily, because these grand challenges were launched with an explicit mandate of engaging and fulfilling the expectations of key stakeholders.

The programs below are presented in rough chronological order of the events which caused their emergence. They include the first discussions of a new research agenda for Europe, the launch of a health-focused science diplomacy program for Canada and a United States' White House agenda for national innovation. To understand the content and context of this case study, I began this analysis by sampling documents from each grand challenge across the lifetime of the program, up until the present day. I, then, combined a rhetorical, qualitative, and content analytical approach to read through these documents; established the context and progression of events within each program; and coded the text into categories as represented by the tables of data samples below (Table 1 and Table 2).

Horizon 2020: Delivering solutions for a new world

The European Union's Horizon 2020 provides our first example of a grand challenge program. Documents published during deliberation and decision-making for Horizon 2020 argue that Europe faces a series of crucial challenges, including low growth, insufficient innovation, and environmental and social challenges. These challenges – in addition to structural problems, such as insufficient and uncoordinated research and innovation by Member States – and a need to strengthen its science base led to a new approach, called Horizon 2020 (EC, 2011).

Planning for Horizon 2020 began with foresight activities undertaken by the European Commission (EC), which were summarised in a Green Paper published in 2007. This paper identified six research areas selected to make Horizon 2020 relevant for citizens and politicians. This Green Paper was the beginning of an attempt to enhance coordination of research activities, so that return on investment from and overall competitiveness of European research would improve (EC, 2007). Its aim was to use research, education, training, and innovation to "fulfil the economic, social, and environmental ambitions of the EU and the expectations of its citizens" (Ulnicane, 2016, p. 13). The Green Paper was

followed by a report issued by an ERA expert group who put forward the grand challenge framework as a way of increasing support and funding for research. In the report, the expert group argued that grand challenges could fulfil a need "for something more to drive ERA forward" and that the challenges would strengthen "buy-in of all major groups of actors and stakeholders." The method for identifying these challenges was informed by global sustainable development goals and European, national, and regional priorities. Ultimately, this meant that approximately sixty percent of the overall budget related to sustainable development (EC, 2011). The Commission "focused continued effort on ERA [Europe's research area] by engaging with a series of Grand Challenges that capture the political and public imagination" (Bina et al., 2017, p. 167). These selected challenges drew on broad social and environment goals in an attempt to change the perceptions of problems, which became opportunities.

During July 2009, a conference on research and innovation "New world – New solutions" was hosted by the Swedish Presidency of the Council of the European Union. Conference attendees included policymakers, researchers, and industry representatives. At the conference, attendees declared that European research policy should address the grand challenges of our time. This declaration – the Lund Declaration – was handed to Dr Tobias Krantz, the Swedish Minister for Higher Education and Research, on July 9. The Lund Declaration was a response to the need to revisit the vision and structure of European Framework Programme, a research policy instrument for the European Union with the seventh iteration of the programme ending in 2013. The audience for this declaration was primarily Member States of the European Union and those individuals and organisations looking to apply for funding from the new iteration of the programme. Within the text of the declaration, claims were made on behalf of the European community.

The Lund Declaration was the first major public announcement that European research should focus on "the Grand Challenges of our time moving beyond current rigid thematic approaches" (Lund Declaration, 2009, p. 1). It set an agenda for an increasing emphasis on climate change, energy, water shortages, food scarcity, global health problems, and security concerns (Ulnicane, 2016). The declaration announced that "Europe must focus on the Grand Challenges of our time" through "best analysis, powerful actions and increased resources". Challenges should "turn into sustainable solutions in areas such as global warming, tightening supplies of energy, water and food, ageing societies" and more.

Responses to these challenges should come in the form of "issue-oriented research in relevant fields" and should engage major stakeholders (Lund Declaration, 2009, p. 1).

Grand challenges are presented as urgent but solvable. They aim to "turn problems into opportunities" (ibid). Meeting these challenges requires "strengthening frontier research", "taking a global lead in the development of enabling technologies", and measures that "maximise the economic and societal impact of new knowledge" (ibid, p. 2). Addressing these challenges presented as a "prerequisite for continued economic growth and improved chances to tackle key issues" for Europe while "bringing about new possibilities and increase[ing] the well-being and quality of life of all" (ibid).

When the declaration was presented to Dr Krantz, it included an addendum which built a case for a revision of the Framework Programme and used grand challenges as an "illustration for what they may bring" (Lund Declaration addendum, 2009, p. 1). The challenge examples – such as climate change, water supply, and public health – were seen to encompass issues that might "emerge incrementally… [or] as crises or even shocks" (ibid). In this context, grand challenges were "radical renewal" of the Commission's approach to research and innovation. A renewal made necessary for a system with an obligation to "generate the necessary new solutions" and provide "opportunities for path-breaking frontier research and paradigm shifts in innovation" (ibid).

The revision of the Framework Programme seems founded on a need to deliver clear benefits to Member States and European citizens. In discussion on the direction of research, Dr Krantz elaborated on three research priorities for the Swedish presidency. These were: enhanced cooperation between "research, education and innovation" sectors, "a new governance structure for the European Research Area… [as] we must be able to argue that money invested in European research is money well spent", and a research framework that "instead of being overly bureaucratic… [is] focused on achievements". He added that addressing grand challenges, "will not only help improve Europe's competitive advantage; I believe it will also make the framework programme easier to understand and more accepted" (Swedish Presidency, 2009, para. 8). Meanwhile, Pär Omling, Director-General of the Swedish Research Council noted in a press release that "the Lund Declaration is a strong plea for increased resources for European research, for better cooperation between different levels and for more edgy innovation systems" (ibid, para. 13).

Grand challenges form one of three priorities for Horizon 2020. Alongside excellent science and supporting industrial leadership, grand challenges are described as requiring major investments in research and innovation to develop breakthrough solutions with scale and scope (EC, 2013). The challenges themselves were identified through trend mapping by the Bureau of European Policy Advisors of the European Commission and the Joint Research Centre-Institute for Prospective Technological Studies. Their *Facing the future: Time for the EU* to meet global challenges report paints a comprehensive picture of issues in the near- and long-term future and examines how the EU can take an active role and influence those issues (ETP, 2010). After conducting a review based on future-oriented literature, the researchers presented key issues at a workshop of experts and policy makers. In this workshop, they worked to transform current and future challenges into opportunities. This led to the identification of grand societal challenges for Horizon 2020 (EC, 2018; ETP, 2010). Those challenges are: health, demographic change and wellbeing; food security, sustainable agriculture and forestry, marine and inland water research and the bioeconomy; secure, clean and efficient energy; smart, green and integrated transport; climate action, environment, resource efficiency and raw materials; Europe in a changing world; and secure societies.

A consultation undertaken in 2011 indicates that the European public was strongly supportive of this new "approach which places EU funding for research and innovation close to societal challenges" (EC, 2011, p. 3). However, increased dialogue between researchers and policy makers, more sharing of research outputs, and better interaction with citizens and civil society continued to be areas for improvement.

Perhaps as a consequence of this public support, grand challenges appear to have been incorporated within the next stage of the European research and innovation framework. A 2017 report *Lab Fab App* on Horizon 2020 argues that the post-2020 program should "translate global societal challenges into a limited number of large-scale research and innovation 'missions'" (EC, 2017, p. 15) with the United Nation's Sustainable Development Goals continuing to serve as a reference point for defining these missions. The missions "should foremost be easy to communicate and capture public imagination and involvement" and should "have a breakthrough or transformative potential for science, technology, industry, or society" (ibid, p. 15). A 2018 budget proposal framed the global challenges pillar as supporting "research relating to societal challenges, setting EU-wide

missions with ambitious goals around issues that worry us daily" (EC, 2018, p. 2). Echoing this sentiment, one report positioned Horizon 2020 as a key asset in sustaining Europe's socioeconomic model and values and its global competitiveness. Although, it also called for more impact and outreach to citizens (EC, 2011). An interim evaluation of the program points to an even more targeted mission-oriented approach so as to define research and innovation missions with "transformative potential" and to mobilise actors and investors into realising this goal (EC, 2018, p. 16).

Grand Challenges Canada: Leadership in global health

A national program funded by the Government of Canada provides our second example of a grand challenge-based program. The program – Grand Challenges Canada – is focused on foreign aid and addresses health issues through research and innovation in low-to-middle-income countries (LMICs).

In a "Responsible Leadership" Budget Plan during 2008, the Government of Canada established a Development Innovation Fund – Health (DIF-H) with an initial $225 million over five years to support research on critical global health problems (Adams, Guimaraes, Atherton, & Franzen, 2015). The organisation "Grand Challenges Canada" was created to implement this fund while the International Development Research Centre and Canadian Institutes of Health Research were engaged to provide oversight and review grant applications. When the fund was announced, the rationale was to:

> "Support the best minds in the world as they search for breakthroughs in global health and other areas that have the potential to bring about enduring changes in the lives of millions of people in poor countries"(Grand Challenges Canada, 2011, p. 5).

The official launch for Grand Challenges Canada took place on 3 May 2010. The launch press release presented the program as a "bold Canadian initiative that will help transform global health through innovation" (Rotman, 2010, para. 17). The Hon. James Flaherty, Minister of Finance for Canada, said that "Grand Challenge Canada will lead the way in making a better, safer and healthier world" (ibid, para. 17). The "uniqueness" of the approach is that "it brings within a country's international assistance budget a large-scale commitment to innovation and global health" (ibid, para. 43). Through this approach, "Canada's role in

international development will be redefined, building our reputation for breakthrough innovation and long-term health solutions" (ibid, para. 12).

While praising the new direction for Canada's international development, the launch focused on the first of five proposed programs with a call for projects that would provide new point-of-care tools for diagnosing illnesses. Dr Peter A Singer, CEO of Grand Challenges Canada, described this focus by stating: "Innovation saves lives. Diagnosis is the prelude to effective treatment. Bringing diagnostic tools to the patient's bedside is better, faster, and cheaper than sending to a sample to a laboratory 100 km away" (ibid, para. 10). In addition, the press release claimed that "diagnostic improvements could save more than 100,000 lives annually from malaria-related deaths alone and could reduce more than 365 million unnecessary treatments, which can lead to wasted resources and drug resistance" (ibid, para. 12). The not-for-profit organisation consequently began several funding streams and partnered with a number of national and international partners, including the Gates Foundation (Ulnicane, 2016).

Grand Challenge Canada's approach to delivering improved global health outcomes is framed through a concept called 'integrated innovation', which combines science and technology with social and business innovation to create impact (Grand Challenges Canada, 2010). The organisation operates as a strategic platform that identifies barriers preventing progress towards solutions for critical problems and works to remove those barriers and bring solutions to scale (Grand Challenges Canada, 2011). Grand Challenges Canada chiefly funds investigators from low- and middle-income countries, in addition to Canadian researchers. Grand Challenges Canada has a clear mandate to build a community of scientists and innovators, to act as a platform for global health diplomacy, and is explicitly focused on capturing the imagination of the Canadian public through its work.

The definition of grand challenge in this context focuses specifically on global health. The organisation defines a grand challenge as "one or more specific critical barrier(s) that, if removed, would help solve an important health problem in the developing world with a high likelihood of global impact through widespread implementation" (Grand Challenges Canada, 2011, p. 9). Under the umbrella of global health grand challenges, the organisation manages three main programs, which are: targeted challenges (Saving Lives at Birth, Saving Brains, and Global Mental Health), challenges to fund innovators who have their own

research focus (Stars in Global Health), and challenges to enable innovations to transition to scale (Adams et al., 2015).

Grand Challenges Canada has been reviewed twice since its establishment, once in 2014 and once in 2015. One evaluation was part of the Government of Canada's review of the Development and Innovation Fund – Health (DIF-H) to ensure continued relevance and performance (Adams et al., 2015). The second was completed by an International Expert Panel and commissioned by the Board of Directors of Grand Challenges Canada (Saucier, 2015). This report assessed the programs impact over five years and provided recommendations for future directions. The Government of Canada's report concluded that DIF-H provided value for money and that continued investment would be relevant to its interests. This conclusion was based on: global health continuing to be a priority in international development and for Canadian development assistance with 78 percent of funded projects were judged as being specifically developed in response to the grant call, the reviewers concluded that the fund was therefore filling a market gap; the boost to Canada's reputation and perception of its international leadership as interviews with international partners indicated that Grand Challenges Canada's leadership role in international global health had been noted; and continued support from the Canadian public. This last claim from the report appears to be based on a general awareness among Canadians that "they are not isolated from the health problems that affect the lives of people around the world"" because individual Canadians contributed $110 million to combating the Ebola outbreak through donations, and, second, that "77 percent of Canadians think it is important for Canada to be known as a world leader in funding solutions to reduce poverty and advance child and maternal health initiatives" (Adams et al., 2015, p. 31).

The report commissioned by Grand Challenges Canada's Board of Directors (Saucier, 2015) found that the program had: achieved significant outcomes in a short period of time and detailed project outcomes from the Saving Lives at Birth program as evidence; promoted Canadian leadership in development innovation because the program was recognised at an event co-hosted by the World Bank Group and World Health Organisation in 2016 and awarded a commendation from the American Psychiatric Association in 2015; stimulated innovation in the target low- and middle-income countries with recipients describing the funding as a unique opportunity in the global health research and innovation

space; developed new models of social finance as an anchor investor in the Global health Investment Fund; and focused attention on critical health challenges with the Saving Brains program resulting in a gradual shift in Canada's approach to maternal, newborn, and child health issues to include the development of children after birth. The focus of both reports was on efficiency and performance in terms of innovations created and lives impacted. Though the numbers varied between the reports, the consensus was that transformative impact has been achieved in the focus area of global health.

UCLA Grand Challenges: Addressing critical issues for California, the nation & the world

Our third example of a grand challenge program begins with a Presidential mandate issued by US President Barack Obama during his first year in office. In 2009, Obama issued a memo that committed his administration to innovation (Obama, 2009). In September of the same year, the White House released the first version of the "Strategy for American Innovation", a policy document to guide translation of research efforts into benefits, including long-term prosperity and well-being for US citizens. Grand challenges were central to this effort with the White House calling for "agencies to increase their ability to promote and harness innovation by using policy tools such as prizes and challenges" (Ziens, 2010, p. 1). This focus was increased within the Obama White House Office of Science and Technology Policy (OSTP) after the hiring of the Assistant Director for Grand Challenges Cristin Dorgelo in 2012.

The subsequent addition of Tom Kalil – who had previously worked in societal challenges for energy, water, and poverty – supported the growing emphasis on grand challenges (Hicks, 2016). In a speech during April 2012, Kalil defined Grand Challenges as "ambitious yet achievable goals that capture the public's imagination and that require innovation and breakthroughs in science and technology" (2012, p. 1). From this time, grand challenges became a central aspect of the President's Strategy for American Innovation and the administration encouraged people to "imagine a world in which more individuals and institutions are involved in pursuing or supporting a Grand Challenge and a world in which these challenges play a more prominent role in our culture and in our public discourse" (Flink & Kaldewey, 2018; Kalil, 2012, p. 5).

President Obama subsequently spoke at the launch of the White House BRAIN Initiative on April 2, 2013. As highlighted in the introduction to this chapter, the initiative

was a grand challenge that focused on advancing understanding of the human brain (Obama, 2013). At the launch, Obama described his administration's commitment to innovation as a way "to grow our economy, to create new jobs, to reignite a rising, thriving middle class" (ibid, para. 3). In this speech, Obama framed the decision to invest in science in terms of patriotic pride in arguing that Americans "do innovation better than anybody else". Drawing a connection between basic science and job creation, he said "we can't afford to miss these opportunities while the rest of the world races ahead… I don't wait the next job-creating discoveries to happen in China or India or Germany" (ibid, para. 14). To support this contention, Obama highlighted how:

> "the founders of Google got their early support from the National Science Foundation. The Apollo project that put man on the moon also gave us eventually CAT scans. Every dollar we spent to map the human genome has returned $140 to our economy" (2013, para. 7).

As if in answer to this Presidential mandate for innovation, the University of California, Los Angeles' Grand Challenges program was positioned as a way of uniting the research of the university's employees and students to create transformative, innovative solutions for society at large.

There is a tradition of grand challenges being leveraged at universities to support interdisciplinary work and realign their research agendas. An instance of this is the University College, London launching a grand challenges initiative to investigate "the world's problems" (UCL, 2019, p. 1). This initiative addressed: global health, sustainable cities, intercultural interaction, and human wellbeing. Grand challenge programs have also been used at Princeton University, Georgia Tech, the University of Exeter, the Australian National University, and beyond. The program outlined here is led by the University of California, Los Angeles (UCLA), which began work on a grand challenges program in 2012 to encourage staff, students, and other supporters to work together to solve critical issues (UCLA, 2018). University faculty participated in an intensive workshop in 2012 to plan out the initiative, which was officially launched in November 2013 with a week of events and an announcement of the first Grand Challenge (Popowitz & Dorgelo, 2018).

The challenges are intended to deliver benefit to "California, the nation, and the world" (Popowitz & Dorgelo, 2018, p. 40). The program encourages its stakeholders to "dream big and think grand about what we can achieve when we set our sights on common

goals" (UCLA, 2019, para. 1). UCLA has positioned the approach as a "new paradigm" for university research (ibid, para. 1) and calls the program the "biggest, most collaborative, and potentially most transformative effort UCLA has undertaken to date" (UCLA, 2018, para. 2). UCLA appears to have adopted the Grand Challenge approach in order to capture public imagination, drive support, and encourage collaboration. It considers the Grand Challenge-approach to be a way to "solve key societal issues" with Cristin Dorgelo noting that:

> "UCLA's campus-wide, interdisciplinary Grand Challenges initiative, with its focus on audacious but achievable goals such as developing new technologies for harnessing renewable energy and water resources, is a promising response to the president's call to action to pursue 21st century Grand Challenges" (Hewitt, 2013, para. 10).

Building on the UCLA Grand Challenge and other similar programs at approximately 20 universities in North America, a workshop was held in 2017 on University-led Grand Challenges to identify opportunities for universities, philanthropists, associations, and industry to advance these efforts through a community of shared practice. The report published after the workshop has been described as a "useful roadmap for universities that are interested in pursuing a Grand Challenge" (Popowitz & Dorgelo, 2018, para. 4). The workshop treated grand challenges as a new opportunity for universities to position themselves as the catalysts of treatments and products and as sources of evidence for decision-making. Grand challenges were considered to be an opportunity to keep publics engaged with the workshop attendees noting that universities would have to plan for a marathon communications effort to ensure continuing support. In the workshop report, UCLA's grand challenge program was described as one of the longest running university-based programs.

The goals of UCLA's grand challenge program are: creating a sustainable Los Angeles (Sustainable LA Grand Challenge) and cutting the global burden of depression in half by 2050 (Depression Grand Challenge). The Sustainable LA Grand Challenge is based on climate change and the environmental challenges of today (UCLA, 2019). The five-year work plan claims "no goal is too grand" in targeting a 100% transition to renewable energy and locally sourced water, while also aiming to improve local ecosystem conditions in Los Angeles (Gold, Rauser, Herzog, & Lueders, 2015, p. 4). This first challenge was launched in November 2013 by the UCLA Chancellor Gene Block who described the project as bigger than any other tackled by the university (Hewitt, 2013).

The Sustainable LA Grand Challenge highlights the role of a critical nexus consisting on local and regional stakeholders as well at the university researchers in achieving these goals. So far, the LA mayor has supported this claim by pledging to significantly reduce the carbon footprint of LA buildings by 14 percent in 2025 and 30 percent in 2035. In addition, spring 2017 saw the establishment of a LA Sustainability Leadership Council, co-chaired by the UCLA Chancellor and LA Major. This council is designed to lead a focused, coordinated effort to make LA the world's first sustainable megacity and will presumably be guided by the five-year workplan devised by UCLA academics. The workplan consists of over 100 research recommendations intended to guide work undertaken to meet the overarching goals of the challenge and will measure progress to these goals through Environmental Report Cards. This grand challenge coincided with the first green "pLAn" issued by the Los Angeles Mayor in 2014. The original plan cites the assistance of Mark Gold, who was also one of the authors of the sustainable LA grand challenge work plan (*pLAn: Transforming Los Angeles*, 2015). The newest edition of the pLAn used the UCLA Sustainable LA Grand Challenge to inform the targets for renewable energy and recycled wastewater ("LA's Green New Deal: Sustainability Plan 2019," 2019).

Meanwhile, the Depression Grand Challenge has been described as the "largest depression study in history [which] serves as a centrepiece for the Grand Challenge" (UCLA, 2018, para. 2). The challenge aims to identify the genetic, biological, cognitive, social, and environmental factors associated with depression (Bauer-Wolf, 2018). Called one of the greatest challenges to global health in the 21st century, the "[number] one source of misery in the world" and a "problem that's as old as humanity itself", the challenge aims to "cut the burden of depression in half by 2050 and eliminate it by the end of the century" (UCLA, 2018, para. 1). This challenge is more recent and less developed than the Sustainable LA program. So far, UCLA has recruited 'leadership' for the challenge and more than $20 million has been invested. UCLA researchers have commenced work with multiple pilot studies contributing towards a study of 100,000 patients. The UCLA Chancellor has also committed to providing screening and treatment for depression and anxiety to all incoming students who need it.

Epideixis in grand challenges: Solving the issues that worry us daily

Here, I guide the reader through the themes which emerged from my grand challenges data. As we have seen, epideictic arguments build consensus by drawing on a community's values and perspectives. In the case of the BRAIN Initiative, President Obama worked to build support for the grand challenge by drawing on a sense of national pride and competition with other nations. Obama argued that without investing in science and innovation, the United States' risks losing out on "job-creating discoveries" and opportunities to other parts of the world (2013, para. 14). He reinforces this drive by reflecting on past American success stories. Notably, this includes the Apollo project that "put man on the moon [and] also gave us eventually CAT scans" in addition to the establishment of Google and the launch of "one of the earliest mini-computers" by an American company (ibid, para. 7). In Canada, the Government adopted the grand challenge framework to establish a global health platform for science diplomacy. With the program acting as a "form of global governance" (Grand Challenges Canada, 2011, p. 15), Grand Challenges Canada assumed a role in international development, in addition to providing research funding, for global health. The Chairman of Grand Challenges Canada described this as an "extraordinary venture which will make such a difference in the world and to Canada's role in international development" (Rotman, 2010, para. 12). Meanwhile, for the European Commission, grand challenges presented an opportunity to highlight the role of science and technology in both protecting the European Union's global leadership in research and innovation and maintaining living standards for European citizens. Here, Horizon 2020 was designed to "strengthen the EU's position in science, strengthen industrial leadership in innovation, and address major societal concerns" (EC, 2013, p. 10).

As Table 1 shows, these arguments reflect tend to focus on what Fahnestock (1986) calls application-centred teleological arguments rather than wonder-centred deontological arguments.

Table 1: Rhetorical appeals within grand challenge programs

Rhetorical appeal	Example
Teleological argument	**Use knowledge as a tool** to turn problems into opportunities and progress (Lund Declaration, 2009, p. 1)
	Taking a global lead in the **development of enabling technologies** such as biotechnology, information technology, materials and nano-technologies (Lund Declaration, 2009, p. 1)
	World class science is the foundation of tomorrow's technologies, jobs and well being (EC, 2013, p. 8)
	Innovation saves lives. Diagnosis is the prelude to effective treatment. **Bringing diagnostic tools to the patient's bedside** is better, faster, and cheaper than sending to a sample to a laboratory 100 km away. (Rotman, 2010, para. 9)
	International leadership in the **use of science and human creativity to improve the health of those who need it** most. (Adams et al., 2015, p. iv)
	Innovation to develop solutions to complex global health challenges. (Grand Challenges Canada, 2012, p. 1)
	Audacious but achievable goals such as **developing new technologies for harnessing renewable energy and water resources** (Hewitt, 2013, para. 10)
	Believe that **for every problem there is a solution** – (Gold et al., 2015, p. 1)
	The goal of this Grand Challenge is to **transition Los Angeles County to 100 percent renewable energy, 100 percent locally sourced water, and enhanced ecosystem and human health by 2050** (Popowitz & Dorgelo, 2018, p. 6)
	The goal of this Grand Challenge is to **cut the burden of depression in half** by 2050 **and eliminate it** by the end of the century. (Popowitz & Dorgelo, 2018, p. 6)
Deontological argument	It promises **more breakthroughs, discoveries and world-firsts** by taking great ideas from the lab to the market. (EC, 2019, para. 1)
	Opportunities for **path-breaking frontier research** and paradigm shifts in innovation (Lund Declaration addendum, 2009, p. 1)
	Strengthen Europe's science base by improving its **performance in frontier research** (EC, 2018, p. 23)
	Support **breakthrough research** on critical global health problems (Adams et al., 2015, p. ii)
	Brings the **best minds** to the table by engaging **world-leading** scientists who might not other be engaged in global health-related research (Grand Challenges Canada, 2011, p. vi)
	Record-breaking solar cell efficiency and reliability research (Gold et al., 2015, p. 16)
	Transforming Los Angeles through **cutting edge research** (UCLA, 2017, p. 3)
	The **largest depression study in history** (UCLA, 2018, para. 2)

As evidenced by the samples presented in Table 1, the overarching rhetoric of the European Commission's Horizon 2020 draws on appeals to wonder by promising "more breakthroughs, discoveries and world-firsts" (EC, 2019, para. 1) as well as chances for "path-breaking frontier research" (Lund Declaration addendum, 2009, p. 1). While these claims were quite prominent for Horizon 2020, Grand Challenge Canada made infrequent use of the wonder appeal. When this appeal was used, the emphasis was on "breakthrough research" (Adams et al., 2015, p. ii) as well as on engaging "world-leading scientists" with global health problems (Grand Challenges Canada, 2011, p. vi). In turn, UCLA's use of the wonder appeal was generally restricted to marketing statements for the grand challenge programs, such as "transforming Los Angeles through cutting edge research" (UCLA, 2017, p. 3) and conducting the "largest depression study in history" (UCLA, 2018, para. 2).

The European Commission has claimed that science and innovation will move Europe towards "smart, sustainable, inclusive growth, and along the way to tackle its pressing societal challenges" (EC, 2013, p. 15). The Commission presents "knowledge as a tool" (Lund Declaration, 2009, p. 1) which will build "world class science" into "tomorrow's technologies, jobs, and well being" (EC, 2013, p. 8). These statements serve the application appeal, although the claims are oblique when compared to the arguments put forward for Grand Challenges Canada and UCLA's Grand Challenge program. For example, within the press release launching Grand Challenges Canada, Dr Singer makes an application appeal in describing the anticipated impact of program for diagnosis. He says that "bringing diagnostic tools to the patient's bedside is better, faster, and cheaper" (Rotman, 2010, para. 9). Meanwhile, the UCLA program is designed to "cut the burden of depression in half" (Popowitz & Dorgelo, 2018, p. 6) and develop "new technologies for harnessing renewable energy and water resources" (Hewitt, 2013, para. 10).

As I have shown in this chapter, the term 'grand challenge' refers directly to a belief that science and technology can shape solutions to the global problems of today. This case study contrasts with the claims used to motivate and legitimate science and technology investment in previous chapters (for instance, the wonder-based claims made for NASA space exploration in Chapter 3). Grand challenge programs are routinely framed in terms of imagined research outcomes through the predominant use of 'application' rather than 'wonder' claims. This reflects the wider shift in research practice towards science that is done 'for and with' society with the need for science and technology to be relevant to

societal needs acting as a common thread for grand challenges. The ramifications of framing research in terms of achievable and urgent problems are unclear. Whereas the Bush 'trickledown' model allowed for creative freedom and unexpected outcomes, the current science-society contract asks for clear deadlines and defined goals. It is then the responsibility of science and technology actors to engage in the moderation of expectations as projects progress, so as to prevent disappointment and backlash (reference about moderating expectations here).

In Europe, the Lund Declaration prefaced a collective need for the European Union and its Member States to address current and future grand challenges through research and innovation. The language of the declaration speaks for Europe on a whole in claiming that "Europe must face" the challenges of "our time" and the issues that worry us daily (Lund Declaration, 2009, p. 1). The use of the grand challenges was a "radical renewal" that would generate "necessary new solutions" of incremental and crisis-level issues through "path-breaking frontier research" (Lund Declaration addendum, 2009, p. 1). With a mandate of both increasing support for investing in research and positioning Europe as a global leader in sustainable development, the declaration laid the foundation for deliberative rhetoric. It argued for an intervention into the direction of science and technology research and development and for legislative change that would remove bureaucratic barriers to research and innovation in Europe.

Similarly, Grand Challenges Canada from the outset has been presented as a "bold" initiative that would "transform global health". With the explicit goal of redefining "Canada's role in international development", the fund is meant to create a "better, safer and healthier world" (Rotman, 2010, para. 7). In contrast to the frontier research mandate of Horizon 2020, the language of this program emphasises application through reference to "innovation and global health." Additionally, the first program launched was directly concerned with tools for disease diagnosis.

The language used to introduce these challenges both celebrates the potential of science and technology and encourages its use to address local problems. In the example from the United States, the UCLA Grand Challenges program draws on language of President Obama in asking participants to "dream big and think grand" to achieve "common goals" and "solve key societal issues" (UCLA, 2018, 2019). For UCLA, these grand challenges present a way to demonstrate the contribution of universities to society where universities

are the source of new technologies and treatments as well as evidence-based policy advice. The grand challenges provide a narrative for communications work, which works to keep key publics engaged with research and innovation. The adoption of the measures suggested by the Sustainable LA grand challenge within the Los Angeles Mayor's sustainability plan ("LA's Green New Deal: Sustainability Plan 2019," 2019; *pLAn: Transforming Los Angeles*, 2015) is one direct way to underscore the contribution of the university to the local community.

These examples of grand challenges situate science and technology as the solvers of urgent societal problems. Within the grand challenges analysed for this case study those societal problems are characterised with universal, generic language that tells us that "we face global risks and must act appropriately, as a unified global community, to counter them" (Miller, 2015, p. 294). Grand challenges operate on a planetwide scale, affecting every individual and their community. In the grand challenges analysed for this case study, Horizon 2020 will ensure "better lives for Europe's citizens"; while Grand Challenges Canada will address "bold ideas with big impact"; and UCLA is solving the "most pressing issues facing society". The focus areas for these challenges are referred to through words such as "sustainability", "global health", and "food security". This use of generic and encompassing concepts allows for "multiple interpretations and specifications" and raises the question of whether researchers adopt them as "window dressing" or clear directives (Bos et al., 2014, p. 151).

As evidenced by the examples of claims presented in Table 2, the visions expressed through grand challenges are at once broad and specific.

Table 2: Types of visions for the future

Types of visions for the future	Examples
Broad visions for the future	Only through sufficient investment in developing our research and innovation capacity can we create the **new jobs and growth to overcome the current economic crisis**. (EC, 2013, p. 5) Smart investment, notably in research and innovation, is vital in order to **maintain high standards of living while dealing with pressing societal challenges** (EC, 2011, p. 2)
	Support the best minds in the world as they **search for breakthroughs in global health** and other areas that have the potential to **bring about enduring changes in the lives of the millions of people in poor countries** (Grand Challenges Canada, 2011, p. v) The Grand Challenges approach is a significant innovation in the field of science for development... It **is a form of global governance** (Grand Challenges Canada, 2011, p. vii) Stars in Global Health is a venture capital-like program that supports exceptional innovators who have **Bold Ideas with Big impact in the area of global health**, and who are based either in Canada or in low- or middle-income countries. (Saucier, 2015, p. 4)
	Established in 2012 with the premise that by working together with shared goals, the UCLA community could have an even **bigger impact on society's greatest problems** (UCLA, 2018, para. 4)
Specific visions for the future	Research and innovation will provide the means to **reduce the Union's dependency on fossil resources and contribute to meeting its energy and climate change policy targets** (EC, 2019, para. 6) **Eco-innovation represents a major opportunity** to boost competitiveness and job creation in European economies. (EC, 2019, para. 3)
	To **create point-of-care diagnostic platforms** that share common standards for use, development and integration. (Grand Challenges Canada, 2011, p. 10) Progress has been achieved: **increasing global attention to maternal, newborn and child health** has led to significant advances. (Saucier, 2015, p. v) Focusing on **interventions that nurture healthy child and brain development in the first 1,000 days of life**. (Saucier, 2015, p. 4)
	A research-based action plan to **achieve three key goals in Los Angeles County by 2050** (Gold et al., 2015, p. 5) This immense, multifaceted effort will **cut the burden of depression in half by 2050 and eliminate it by the end of the century**. (UCLA, 2018, para. 1)

Taken at face value, the rhetoric of Horizon 2020 dictates that researchers will turn problems into opportunities for Europe as their research creates "jobs and growth to overcome the current economic crisis" (EC, 2013, p. 5) as well as a way to "maintain high

standards of living" (EC, 2011, p. 2). A lack of measurement in the form of metrics beyond classical research outputs (publications and patents) makes it difficult to determine whether this grand ambition is on its way to realisation with a review of the societal challenges from Horizon 2020 highlighting multiple areas for improvement. These included: "insufficient focus on areas where the greatest impacts are expected" and [a] "lack of clear SMART [Specific, Measurable, Achieveable, Realistic, and Timely] objectives" (EC, 2018, p. 173). Meanwhile, Grand Challenges Canada articulates visions of new "breakthroughs in global health" and a fresh, innovative "form of global governance" while also directing focus to diagnostic platforms, newborn health, and brain development in the first 1,000 days of life (Grand Challenges Canada, 2011, p. v-vii). Impact in this area of global health is measured by the 8,689 lives saved and 160,000 lives improved through projects funded (DIF-H 2015). Likewise, UCLA makes broad claims to have "an even bigger impact on society's greatest problems" and is able to measure progress towards its "three key goals in Los Angeles Country" through environmental improvement metrics (Federico, Rauser, & Gold, 2017; Gold, Pincetl, & Federico, 2015; Gold et al., 2015, p. 5).

In these examples, we see the work of epideictic rhetoric as the advocates for grand challenge programs work to achieve consensus for projects through an intensification of select values. These values link "the power of science and technology to describe risks and propose solutions to the power of social and political institutions to fashion order" (Miller, 2015, p. 294). Use of vivid language is a standard tactic in epideictic rhetoric to emphasise values. In Table 2, samples of such language include research and innovation that will help "overcome the current economic crisis" and "pressing societal challenges", "bring about enduring changes in the lives of millions of people", and "impact on society's greatest problems." More specifically, the challenges are designed to "boost competitiveness and job creation", "nurture health child and brain development in the first 1,000 days of life" and "eliminate [depression] by the end of the century." Epideictic rhetoric also draws on shared social responsibilities in order to create a sense of community identity and bring about action. For grand challenges, this has produced programs, designed in response to tipping points for society with the aim of generating collective, coordinated action. The clearest instance of this is the UCLA Sustainable LA Challenge which works to combat climate change and create a sustainable Los Angeles.

Science for and with society

Grand challenges can be socially complex or technologically complex according to the literature investigated in this thesis. A socially complex grand-in-scope challenge works across multiple levels of action, involves societal stakeholders, and is noticeably global by definition. By contrast, a technologically complex grand-in-difficulty challenge is concerned with technical difficulty and technological fixes (Efstathiou, 2016). However, the examples that I consider for this chapter were not distinctly one or the other. Instead, they shared features of each category. Horizon 2020, for instance, is at first appearance a grand-in-scope challenge as its seven societal challenges determined by European and global sustainable development priorities. The European Commission also presents a mandate for science for and with society, meaning that most projects have an obligation to engage with their societal stakeholders. Yet, the lack of metrics makes it difficult to determine whether that grand scope is realised in practice and the case studies put forward in the interim 2017 evaluation report seem more akin to technological fixes. Examples in this report included: *Immunovia AB* – a blood test diagnostic for pancreatic cancer; *COMPARE* – a genome technology to speed up detection and response to disease outbreaks in animals; and *POWERSTEP* – research on converting sewage-treatment plants into power-production facilities (EC, 2018).

Similarly to the grand-in-scope challenge definition outlined above, Cagnin et al. (2012) argue that for a grand challenge to amount to more than a technological fix, actors must consider the changes required in human perspectives in addition to behaviour and social innovations that put forward non-technological solutions. Horizon 2020 attempts to address these more social elements through the *Science for and with Society program*. This program aims to "build effective cooperation between science and society, to recruit new talent for science and to pair scientific excellence with social awareness and responsibility" (EC, 2019, para. 1). However, the interim evaluation of the program identifies an "underrepresentation of civil society and private companies in funded actions overall" (EC, 2018, p. 173).

With a focus on bringing health products to market, Grand Challenges Canada appears to be an example of a technology accelerator. One example that supports this view is a project which was focused on the introduction of low-cost breast ultrasound scans in Uganda health care systems (Grand Challenges Canada, 2018). However, the integral model

for Grand Challenges Canada – *Integrated Innovation* – is based on the premise that aligning science and technology innovation with social and business innovation results in increased effectiveness and impact (Grand Challenges Canada, 2012). This concept and the customisation of solutions and training for different communities indicates that elements of a grand-in-scope challenge may be in play. For example, *Aakar Innovations* is a Grand Challenge Canada funded-Indian social enterprise that provides access to affordable, biodegradable sanitary pads while seeking to influence taboos and gender norms on menstruation in rural parts of India (Grand Challenges Canada, 2018). Grand Challenge Canada also touches on aspects of the grand-in-scope challenge by engaging with societal stakeholders for relevant projects to ensure uptake and behavioural change.

Both of the UCLA grand challenges are focused on delivering solutions to urgent crises within identified communities; they require multiple levels of action and are 'everybody's problems.' However, the sustainability projects detailed in the UCLA research portal are predominantly technology focused though some address the need for policy and behaviour change. These research projects include a study focused on providing datasets for comparative analysis and modelling of drought impacts and a study that aims to create a transformative and distributable new energy technology based on an integrated spectral amplification system. Similarly, the Depression Grand Challenge is chiefly concerned with studies that enhance detection and treatment of the illness.

Do grand challenges offer a research agenda more appropriate to our time? Hicks claims that the grand challenge "combines intellectual and practical motives, generating excitement to address problems so big they exceed the capacity of specialist communities" (2016, p. 39). As part of this generation of excitement and the creation of visions for the future, grand challenges are presented as allowing funders, researchers, and other actors to work together to propose solutions for global issues and to support increasing large and collaborative research structures. This imagining work is meant to engage and move people, organisations, and funding as well as the 'public imagination' through pictures of a 'better' world. In this context, the rhetoric of grand challenges aims to present serious problems as urgent and yet manageable. Yet, and as I have shown, grand challenges also appear to draw on the characteristics of 'silver bullet' claims in that they address technical progress, generic application, and scalability and focus on the deployment of technology instead of

considering (and perhaps challenging) existing social norms and structures (Brooks et al., 2009).

For the promised impact – the 'transformative innovation' – of grand challenges to be fully realised, the role of society and civil actors as "innovative collective(s) instead of simply consumers" should be recognised (Daimer et al., 2012, p. 231). This leads us to the question: Is the rhetoric of public involvement in grand challenges 'just' hype? Or, does it influence the implementation and conduct of research by encouraging the integration of broader, non-specialist communities and individuals?

In documentation for Horizon 2020, references are frequently made to research and innovation delivering benefits to "all types of stakeholders – including citizens" by addressing societal challenges that affect them daily (EC, 2018, p. 64). Responsible Research and Innovation – an anticipatory governance approach – is employed to support the participation of civil actors. The researchers themselves feel that the program addresses citizens needs and occasionally cite the increased involvement of civil actors as a priority (EC, 2018). Despite this, the examples provided of civic actor engagement are restricted to outreach-style events, single moments that make the science available and which seem to function as a chance to promote STEM careers to the younger participants.

Grand Challenges Canada makes explicit reference to social innovation within its core concept of *Integrated Innovation* in the sense of recognizing the broader social, structural, and political factors that influence health and highlight the need to address one or more of these to improve health outcomes (Grand Challenges Canada, 2012). Where relevant, *Integrated Innovation* is encouraged through: criteria used to assess research proposals, the selection of reviewers for committees with social and business expertise, and ongoing confirmation from grant holders that project milestones to identify and address barriers to scale. In this way, Grand Challenges Canada attempts to ensure that "Integrated Innovation is not just a concept that potential grantees must address and consider in their proposals; it is an ongoing part of their projects" (Grand Challenges Canada, 2012, p. 2).

The UCLA Grand Challenge program also attempts to bring together researchers and community to 'solve society's toughest problems.' In the Sustainable LA Grand Challenge, the establishment of the LA Sustainability Leadership Council (which consists of local community representatives) and the LA Major's own commitment to a "Green New Deal" for the county has helped emphasise the role of community and business groups.

Specifically, the Mayor's sustainability website argues that tackling these challenges will require that " everyone does their part – our community partners, non-profit groups, the private sector, academia…. Each of them can use this plan as a platform for action"("LA's Green New Deal: Sustainability Plan 2019," 2019, para. 1). By contrast, calls for involvement in the Depression Grand Challenge are focused on participation in studies geared towards diagnosis and treatment.

Grand challenges are, so far, predominantly top-down in organisation. They appear skewed towards technological solutions and yet appeal to a wider societal mission to create and ensure a 'better' world. The publics of these programs appear to be simply enrolled into predetermined technoscientific agendas and futures, which may in fact mean that alternative socio-technological pathways and different ways of approaching research are missed (Felt et al., 2007; Raman & Mohr, 2014). Part of the difficulty in accounting for societal impact in these grand challenges also lies in the absence of metrics that go beyond classic research outputs, such as publications and patents. This obstacle may yet imply more change is coming for research practice. Specifically, in terms of how the outcomes and outputs of research are measured.

Conclusion: An unfulfilled mandate?

In this chapter, hype has been used to advocate for research agendas based on grand challenges that tackle the 'big' problems of our time. When researchers write funding applications, they are often asked to look five, ten, and twenty years into the future to account for the potential social, economic, environmental and other impacts of their proposed work. On the flipside, research funders design programs to engage the expectations around possible outcomes for their own stakeholders, such as politicians and policymakers. This, in turn, must engage those stakeholders' publics, such as local communities in a politician's electorate. In the grand challenge examples considered in this case study, research programs have been framed through societal needs in part to meet this need to engage the expectations of stakeholders. Here, I have outlined the contradictions that have so far been inherent to such programs as they work to fix societal problems through solutions centred on technology and science. This begs the question: should the futures that inform grand challenges be subjected to public imagination and reimagination?

How might that reimagining help guide the imperative(s) and design of research in grand challenges and otherwise?

Grand challenges are founded in visions of the future. Their advocates anticipate the problems that 'worry us daily' and present solutions in the form of research agendas. In doing so, they open the way for anticipatory governance of science and technology. Anticipatory governance covers a broad stretch of activity, including predicting the results of research, engaging with publics with research as it is conducted, and inviting those publics to participate in some way with the design, or re-design, of the work (Guston, 2012). In a narration of how anticipation influenced the governance of atomic weapons, Guston argues that governance of research – anticipating its outcomes and mitigating undesirable impacts – is inherently plausible. He describes anticipatory governance through the metaphor of a puzzle and writes that this work is about "having enough of the pieces turned up that you begin to appreciate what the complete picture might be" (2012, p. 14). These grand challenges are used to invoke imaginaries of better futures by promising to address the big issues of climate change, sustainability, security, depression, global health, and more. Within the examples of grand challenges analysed here, the framing of science and technology as a solution to societal problems may yet narrow broader perceptions of our collective future. This is a potentially problematic use of hype. For grand challenges to truly address the 'problems that worry us daily', science and technology actors need to enable participation by civil actors in the anticipatory work that goes into shaping the programs and research projects. This would allow for the re-design of research solutions and the identification of problems that are relevant to different communities. The examples in this chapter provide some insight into the current state of civil actor engagement and participation and report on varying degrees of success.

The framework of epideictic rhetoric adopted here presents one avenue for participation beyond a rather literal contribution to the 'doing' of research. In Chapter 6, I will expand upon this avenue, which speaks to the literature around convening publics. In brief, it builds upon the role of the audience in epideictic rhetoric, in which the audience evaluates the competence of the speaker and the content of their speech. This role speaks to the emergence model of science communication outlined in chapter 1 where re-establishing a link between science and democracy requires open and critical discussion from both scientists and citizens (Irwin, 2001). For this case study, the strongest traces of

evaluation-focused role are found in the UCLA sustainability grand challenge. Here, creating a sustainable Los Angeles requires multiple levels of action and engagement from the community. Work to establish this engagement has begun with the establishment of the LA Sustainability Leadership Council and strong buy-in from the LA Mayor and participation of community and business groups.

This account of hype also links to anticipatory governance and the requirement for science to take the needs of society into account. In the following concluding chapter, I build on this discussion to examine how this account opens the way for a revised role for hype in creating and involving publics in science and technology.

Chapter six: Conclusion

Can hype be a force for good? In Chapter 1, I motivated this question by reflecting on how hype might contribute to increased democratisation of science and technology. As I described in the introduction, hype mobilises select futures through creating promises and expectations. It is that very future-focused work that raises the possibility of using hype to unearth the buried assumptions that informed previously unquestioned narratives and, in doing so, identify different pathways for innovation.

When science and technology actors engage in hype, they anticipate the outcomes of research and development. This anticipatory work takes the form of visions and stories, articulated through optimistic or pessimistic expectations. Visions of desirable futures to work towards, or undesirable futures to work against, help to motivate support for research and gather necessary resources, including funding and political capital. From research proposal through to commercialisation, science hype occurs at all stages of the research process and it is produced by all manner of science and technology actors. Research students and researchers, press officers and journalists, universities and government departments all engage in hype as they imagine and invent technoscientific futures. The pervasive nature of hype means that there is no shortage of examples to choose from for research. In the case studies I examined, hype was a way of articulating the future of scientific research and technology development. Hype, in a sense, prototyped those futures by establishing the viability and potential of the topic at hand.

The structure of my concluding chapter covers the key findings of my thesis and three perspectives on hype in science before addressing the limitations of my research and providing concluding remarks. Here, I offer a more complete description of hype in science. I read across the case studies covered in this thesis and provide an account of the role hype plays in the creation and realisation of technoscientific futures. In doing so, I make note of how the use of hype does not guarantee 'lock-in' for specific futures. Indeed, the realisation of technoscientific futures depends on more than hype, it also requires the enrolment of other actors and publics to the agenda at hand. By highlighting this, I am attempting to provide a counternarrative to the story in which hype and hype alone is the problem. Ultimately, the use of hype comes down to how individual and collective actors manage and

create expectations along the research and development journey, the research system that allows and sometimes demands this work from them, and how these actions enable (or not) other publics to participate in the design and production of shared futures.

The short answer to the overriding question for my thesis is "yes, when…". I contend that hype has the capacity to bring people together by invoking new publics, speaking for them, and provoking a response. Hype also has the capacity to shut down alternative pathways for innovation and other science and technology-driven futures. No single theoretical tradition can help us make sense of these contradictory effects of hype. To address this, I brought together research on sociotechnical imaginaries, anticipatory governance, and the notion of convening publics. Together, these areas of research provided a deeper understanding of how: futures are envisioned and built; alternative views are invited and fostered; and responses from different publics are sparked. In the discussion that follows, I elaborate on these points as I argue that hype can be a force for good.

In my Journey to Mars case study (Chapter 3), I demonstrated how hype can be used to frame select futures and direct attention away from alternatives. I built on this understanding in my quantum technologies case study (Chapter 4) to explore how hype generates momentum for investment and national support of a field. This second case study also invited reflection on how hype draws attention to an issue in a way that can spark unanticipated conversations on the implications of new science and technology. Finally, in my grand challenges case study (Chapter 5) I examined how societal relevance is framed and operationalised within research agendas. Within this case study, the notion of publics as convened also came to the fore when I examined the tension between the growing mandate for deeper, upstream engagement with publics and current research practice.

The key contributions of my thesis to science communication research are based on: my conceptual framework, which adopts concepts from three distinct fields of research; the breadth of the distinct examples of hype examined through my case studies; and the depth to which those case studies were interrogated. These contributions are further developed below. The account that I provide of hype in science is also distinct from current science communication offerings on this subject. Whereas science communication analysis of hype is usually restricted to specific sources along the 'hype pipeline', my thesis offers a holistic view of how hype begins and grows within the broader communicative ecosystem of science and technology. My research has been directly influenced by my role as a hybrid

science communication researcher and practitioner and I reflect on the insights gained through this role in this chapter.

Overview of chapters

Within this overview of chapters, I account for the place of each chapter within the overarching focus of this thesis. I also show how aspects of my conceptual framework combined to better describe the effects of hype in the science and technology ecosystem.

In the introduction of this thesis, I described the perspective I would take on hype. A neutral perspective, which made no assumption around the use of hype being good or bad. I then drew on three fields – science communication, STS and public relations – to examine different perspectives on hype in science. Within Chapter 2, I mapped out the current research from these disciplines as well as the methodologies I used for my own research on hype. In doing so, this chapter answered the first of my subsidiary research questions: "how does science communication characterise hype?" while highlighting the dilemma that hype poses.

The dilemma of hype in science communication is that, on one hand, hype is a monster of exaggeration, inaccuracy and deceit, and, on the other, a helpful tactic garnering vital support for the advocates of technoscientific futures. Hype inevitably highlights the assumed benefits of science and technology while underplaying cost and risk. This dynamic means that a discourse of hope and promise carries the constant threat of disappointment and despair. By incorporating anticipatory governance and the notion of convening publics (for instance, through the emergence model) within this thesis, I have attempted to counter this threat. Furthermore, and in line with literature on hype as a rhetorical trope, I propose that we view hype as an opportunity to initiate interaction and explore the promises and concerns evoked by technoscientific futures. This more constructive approach both accepts the current need to hype research and builds on a contemporary call for responsible research and innovation, which asks that our collective futures be co-designed by civil and science and technology actors. Hype potentially allows for this co-design by drawing in publics and prompting their response. I demonstrated my rationale for uniting these sources of literature through an analysis of three models of hype in science, described through the stages of a historical case of hype: Pons and Fleischman's cold fusion.

In contrast to this example of hype, the three case studies investigated in Chapters 3 through 5 were contemporary examples of hype. In science communication research, working with historical and contemporary examples presents different opportunities and difficulties. Historical examples are 'complete' in the sense that the researcher can chart the aftermath of developments and provide a holistic view of how events unfolded. On the other hand, contemporary examples are limited in that the aftermath is unknown, but the researcher has a more active role in that by conducting timely research they may have a greater ability to influence what occurs. This active role is perhaps more aligned with the contemporary agenda of anticipatory governance in that science communication researchers who are embedded with other science and technology actors may have the opportunity to ensure reflexivity and self-criticism in science (Bandelli, 2015; Horst, 2007; Irwin, 2001).

In Chapters 3 to 5, I analysed three case studies to illustrate how hype is shaped in different social and cultural contexts. The study of these different contexts was aided by the addition of the sociotechnical imaginary to my conceptual framework for this thesis. For this thesis, the sociotechnical imaginary helped reveal the relationship between incidents that might otherwise appear separate or unrelated. This contribution to my framework helped demonstrate how expectations and visions can form physical and political instruments of change while recruiting additional actors and making space for new technologies or research. It also helped answer my second subsidiary research question: "How can hype be understood as part of the communicative landscape of science and technology?"

Each of the case studies cover a distinct story of hype in science. They offer an account of how actions and messages have built specific visions for human exploration of Mars, national agendas for quantum technologies, and solutions to the grand challenges of the twenty-first century. In addition to these individual accounts, the case studies relate to one another in the way hype has mobilised certain visions for the future and in the positioning of science and technology as a central part of those visions.

A dilemma between creating short-term buzz and long-term visions was where we first met the case study presented in Chapter 3. This case study represents the most traditional approach within my thesis. As in the majority of science communication research on hype, I looked chiefly at press releases and media coverage to understand how NASA was shaping expectations for a human presence on Mars. Between 2014 and 2016, NASA met

the challenge of creating extraordinary but feasible futures by prototyping their mission to Mars through the film *The Martian*. With human missions in space being more likely to increase public awareness of NASA's endeavours (Cokley & Angus, 2014), this film was an ideal opportunity to demonstrate the viability of a human presence on the red planet (Zhang, 2015). NASA's vision for space exploration in the 2030s came to life in the film, which also provides a link to the metanarrative of NASA's ongoing communication campaign 'NASA's Journey to Mars.' In this campaign, human space exploration and a human presence on Mars is a worthy journey, an advancement for humanity, and the subject of an internal political war and international competition. Here, the imaginary crafted and encouraged by NASA puts the space agency centre stage in space exploration for the foreseeable future. This role of hype speaks to its agenda building and setting capabilities and opens the way for discussion on how alternative visions of the future can be introduced.

At the same time that NASA's campaign was underway in the United States of America, the United Kingdom was producing its first report after the Chicheley Hall meeting on quantum technologies. In Chapter 4, I outlined how this acted as the first open declaration that a nation was looking to create a national strategy for quantum research and technology development. Just two years later in 2016, the Canadian National Research Council launched proceedings towards their own national Quantum Canada initiative. This was around the same time that lobbying began in earnest for a national quantum program in the United States. The imaginaries that informed these activities show the different social factors which shaped each nation's approach to achieving leadership in the 'quantum race.' While the United Kingdom and Canada emphasised the economic gain that accompanies the development of quantum technologies, the United States was more focused on issues of security and safety. What these strategies do agree on is, at a national level, the development of quantum-enabled technologies is intensely competitive with each nation striving to achieve a critical mass of talent and technology. In contrast, the interviews I conducted and the events I attended indicated that individual physicists were more concerned with what could be achieved through collaboration. This is interesting as the imaginaries invoked by each nation also appear to have been shaped, at least initially, by the research community, which indicates a high level of awareness regarding what messages best influence the decisionmakers with access to political and financial resources. This case study provided insight into how the external hype, which influence how society at

large makes sense of new technological developments, is shaped but also contested by insiders.

Sociotechnical imaginaries "can become integrated into the discourses and practices of governance, and thereby structure the life worlds of larger groups, including entire nations and even transnational communities" (Jasanoff and Kim, 2015, p. 329). The imaginaries present in the quantum case study originated within research communities and spread to governing bodies. In Chapter 5, the third and final case study for my thesis, the reverse occurred with imaginaries that were nurtured first by science policy circles and philanthropic organisations entering the discourses of national funding bodies and governments, and from there influencing the projects of researchers. The imaginaries in question were grand challenges for research and they are designed to tackle the 'big' problems of the twenty first century. The advocates for grand challenges anticipate that the outcomes of large-scale research can address issues such as climate change, water scarcity and global health (Gates Foundation, 2003; Kalil, 2012; Lund Declaration, 2009). Horizon 2020, Grand Challenges Canada, and UCLA Grand Challenges program are three examples of research agendas which have been designed around this fundamental premise. Grand challenges also presuppose that the research projects addressing these big problems will enrol and engage publics affected by those problems along the journey. At present, this assumption is – to varying degrees – an unfulfilled mandate for the grand challenge programs that I examined with the rhetoric of funders addressing societal concerns more often than the projects themselves. These grand challenges provided hints of how hype might be used to convene publics by speaking to the collective, shared issues that 'worry us daily.'

These issues that worry us daily were primarily presented in the grand challenges case study through epideictic rhetoric that centred on appeals to 'application'. These appeals were concerned with how research in various forms could have an impact on global and local problems, such as sustainability and health. In contrast, the rhetoric within the Journey to Mars case study was driven by appeals to 'wonder' with a human presence on Mars characterised as a 'first' and a 'breakthrough' moment for space exploration.

In the three case studies considered in my thesis, hype has been adopted to advance rhetoric concerned with competition, global leadership and societal benefits. The events documented in these case studies have affirmed the ideal of science and technology

ensuring progress and advancement. However, within the last case study, a different narrative has begun to emerge. This narrative is one which questions science's right to self-governance with a shift towards anticipatory governance. For the moment, the rhetoric appears to be resulting in a confusing blend of outreach and engagement-style activities instead of truly participatory research co-design. This new narrative opens the way for discussion on how hype might be repurposed in aid of science and technology that is created with, rather than for, society. It also helps answer my third subsidiary research question: "How might hype contribute to the democratisation of science communication?". The overarching framework of sociotechnical imaginaries can help here. As well as explaining and analysing coalition-building work, imaginaries can work in resistance "sometimes raising impediments to the spread of new ideas and at other times crystallizing the dissatisfactions with the present into possibilities for other futures that people would sooner inhabit" (Jasanoff and Kim, 2015, p. 329). When coupled with the convening nature of hype – which is to say, the capacity of hype to bring together publics – this potential for resistance or insistence on change might just reinforce calls for research to be co-designed.

Hype works – intentionally or not – as an invitation for the contribution of other publics. As I noted in Chapter 2, anticipatory governance is concerned with anticipating research outcomes and engaging with publics as research is done. As Guston writes, "these capacities will create our best chance at not blundering into synthetic biology, nanotechnologies, and geoengineering as we blundered into the atomic age" (2012, p. 12). But, how might this engagement with publics occur? I argue that hype represents an opportunity to call out to others by attracting their attention. In contemporary life, the conditions of democratic public life have expanded (Barnett, 2008) with people entangled in relationships of cause and effect. Here, actions have multiple indirect consequences and publics are created or convened by claims to either speak on their behalf (this research is what the public wants) or act in their interest (this research is in the public interest). Publics may then come together because they concur, disagree, or otherwise react to these claims.

This returns us to the link between democratic decision-making and communication in which communication carries ideas in the open and enables participation. To adopt Heath's (2006) call for a paradigm of public relations that recognises its ability to add value to a fully functioning society, persuasive communication (and hype) here would look to societal good and contribute to the responsiveness and inclusiveness desired by anticipatory

governance (Brown, 2014). Through an increasing emphasis on the agency of publics, this paradigm recognises that participative communication requires an opportunity to choose to respond. To draw this out for anticipatory governance in research, one might argue that science and technology research is not final until relevant publics react to either incorporate work into their day-to-day world or reject it altogether.

Can hype be a force for good?

How, then, does my research in this thesis come together? What recommendations can I make on hype, bearing in mind the benefits and the drawbacks of this rather touchy subject? Here, I outline three possible perspectives on hype in science: an optimistic, instrumental perspective hype that focuses on its capacity for agenda setting; a more wary, pessimistic view in which the drawbacks outweigh the benefits; and a pragmatic perspective that addresses the convening nature of hype.

An instrumental perspective on hype

What advantages does hype provide for science and technology actors? The positive, instrumental perspective on hype presented here is primarily concerned with hype's agenda setting properties. As described Chapter 3 and 4, hype can drive political and social support for science and technology agendas and allow advocates to gain access to vital resources.

In the case of Chapter 3 and NASA's campaign for human exploration of Mars, hype played a crucial role in fostering expectations and a vision of how the agency would operate on the red planet. This was important as advocacy in general plays an important role for a field that is highly risky and very expensive (McCurdy, 2011; National Press Club, 2015; Starr, 2008). NASA in particular has a need to constantly engage and re-engage its stakeholders to ensure political support and funding (Dittmar, 2008; Penley, 1997; Taylor, 2015). In practice, NASA published over a hundred press releases in a three-year period that specifically mentioned Mars. Each of these press releases provided incremental updates on robotic missions on and to the planet and other details on NASA's eventual plans to establish a human presence there. Considered collectively, these press releases painted a picture of a cohesive, strategic communicative campaign with the aim of making NASA's research and plans visible and shareable. The media coverage written largely in response to these press releases consistently presented Mars as an unquestionable goal for human space

exploration. Reaching the red planet was considered to be ambitious, exciting, and worthwhile, even in a time of political budget cuts. With *The Martian* acting as the perfect vehicle for presenting a picture of a NASA presence on Mars, the Journey to Mars campaign even influenced discussion in the United States space subcommittee at a time which NASA's budget was subject to uncertainty and debate. This is one example of how hype can be used as a tactic for advocating on the behalf of science and technology through the creation of desirable and seemingly inevitable futures. The findings of this case are broadly generalisable to other science and technology fields that require substantial support in the face of unknown and even unlikely returns, such as quantum physics and quantum-enabled technologies.

In Chapter 4, I detailed how quantum physics has undergone a transformation over the last twenty years from a field concerned with fundamental research to one with promising technological applications. 'Promising' is the key word here with advocates lobbying for public and private funds required to progress research towards potential quantum-enabled technologies. For this field, hype has been a matter of framing expectations within stories of future success (Brown & Michael, 2003; Schyfter & Calvert, 2015). Expectations of impact from quantum technologies in sectors such as finance, defence, and mining have informed a long-running narrative in order to drive increasing support for quantum research and development. In the sample of quantum rhetoric reviewed in this thesis, momentum for national quantum strategies has been mobilised through rhetoric of competition, economic gain, and threats to security. The framing of these strategies tell us about the underlying imaginaries which encourage organisations and countries to back one field over another. The use of this framing in lobbying indicates the language politicians and policymakers find persuasive with frequent references to 'useful' investment that would create economic opportunities and jobs.

In these examples, hype is used to grab publication attention for science and technology and to define how science and technology should be thought about. The approach described here implicitly shuts down alternative pathways for innovation. In that sense, this is an instrumental account of hype. In a similar sense to Gartner's approach (2015) to hype, in which hype acts as an indicator of a technology's maturity and potential for return on investment, hype is a tactic to adopt while advocating for a particular science and technology vision. This use of hype can be problematic. Drawbacks of this problematic

hype can include a lack of ability to deliver on or moderate promises which then leaves a vacuum of expectations and hope. These ramifications will be expanded upon in the next section. In the two examples outlined above, a capacity to present a clear vision of the future (NASA) and to deliver a related piece of technology (quantum) aided advocates in their quest to promote a particular view of the future. However, as we will discuss in the next section, this was not the case for stem cell science in the late twentieth and early twenty first century.

When the drawbacks outweigh the benefits

The pessimistic view of hype presented here is primarily concerned with the drawbacks of hyped up promises for science and technology. This section presents some of those drawbacks across some of my case studies and other examples of science hype.

In Chapter 3, we encountered NASA's long-running communications efforts to advocate for human space exploration. This advocacy work is representative of a broader condition in science and technology where individuals and groups exist in a state of competition and attempt to frame their work as the most important and deserving of attention and support. The dilemma posed by this condition is the potential for attention deficit, which is to say that people have a limited capacity to attend to the plethora of issues they are confronted with each day. Do other topics go unacknowledged when airtime is dominated by discussions of human exploration of Mars?

The building of hype on the national scale around emerging quantum technologies was made apparent in Chapter 4. While this messaging has led to the establishment of national strategies and further support for the field, it has also led to some backlash. In one example, a recent article published in *The Guardian* by Sabine Hossenfelder criticised the 'world changing' promises for quantum computers, arguing that the challenge of scaling up the machines to something truly useful is a formidable challenge (Hossenfelder, 2019). The level of hype in the field has led some insiders to speculate as to when the 'quantum bubble' might pop and a quantum winter (a dearth of funding and support) might emerge.

A similar scenario around hype for stem cell research (Chapter 2) fostered a growing and troublesome stem cell tourism industry. The fostering of unrealistic expectations has been problematic for the potential end-users of promised treatments, i.e. the patients of intractable conditions and their carers. The drawbacks of hype for this sector are plain; the

overpromising of exciting and revolutionary treatments has contributed to a constant juggling act where statements must come with a disclaimer of 'we are not there yet, but in the right conditions we will make progress.'

The points raised here speak back to the reservations towards hype expressed in science communication literature. When hype is used to highlight the benefits and avoid discussion of the risks and costs of research, fields may be overinvested in and wider publics may be led to believe in unlikely outcomes. This problem is compounded by wider sociocultural and politic-economic processes in which discourse of hope and promise are sustained by multiple parties, including researchers, governments, and industry. This not only raises the potential for increasing cynicism when new technologies and treatments do not eventuate in the timelines promised, but also makes people vulnerable to false hopes created by less responsible actors.

The dilemma that science and technology actors face is: what can be done to mitigate or provide nuance in such instances of hype? Calls to stop the hype do not seem to have much impact (Maleszewska, 2013; Rinaldi, 2012).There is little to show in terms of slowing down use of 'breakthrough' or 'world-first' themed abstracts, press releases and media coverage (Vinkers et al., 2015). The potential and actual drawbacks make it impossible to deny that there are problems with hype, but it is equally valid to argue that the devil is in the detail with examples of destructive and constructive hype. While no simple solution is available, this does lay the groundwork for a third perspective on the role of hype in science and technology, in which hype might be considered a force for good.

A pragmatic take: Using hype to convene publics

As outlined in Chapter 2 and demonstrated in the case studies analysed in this thesis, advocates in science and technology foster expectations and visions of the future (hype) to build support and resources. The promises made through these narratives of scientific and technological progress are "by definition, a projection into the future of a desired state of affairs, [and are] associated with a commitment to deliver this state" (Apreda et al., 2014, p. 370). However, these promises are not always achievable within short timelines and the outcomes that are achieved may not quite match with the initial expectations fostered by advocates. As note, Borup et al. note: the cost of these expectations and frequent disappointments can include "reputations, misallocated resources and investments" (Borup

et al., p. 290). And yet despite these risks, committing to visions of the future continues to be a central part of the communicative ecosystem of science and technology. How then might this situation be managed?

In Chapter 1 and 2, I established relationships between persuasive communication and democratic publicness as well as hype and approaches to anticipatory governance through my conceptual framework. In doing so, I suggested that hype might be used to invite conversation and debate over technoscientific agendas and the assumptions that inform them. I expand upon this perspective on the role of hype in science below.

In an exploration of the relationship between science policy and public opinion, Irwin (2001) argues that "the relationship between science and democracy should not be about the search for universal solutions and institutional fixes, but rather the development of an open and critical discussion between researchers, policy makers, and citizens" (p. 16). The role of science communication in this context is in constructing, reviewing, critiquing, and challenging such processes. However, science communication approaches themselves can be an obstacle to this role. As I outlined in Chapter 1, the default models of science communication supply set roles for citizens (Horst & Michael, 2011; Michael, 2012). Indeed, dialogue events can be a site of struggle "between old and new forms of relationship management between science and society" in which public participants report their knowledge and expertise is devalued (Davies, 2010, p. 413). In these events, the structure of discussion itself is not open for reinvention by all and sundry, but rather remains the dominion of those experts. Meanwhile less concrete but still powerful constructions of the roles of actors through performative expectations shape the conditions for engagement with science and technology (Horst, 2007; Kerr et al., 2007).

Within this context, how might open and critical discussions be provoked or made real? As addressed in Chapters 1 and 2, rhetoric plays a distinct role in science. First, in creating theory for analysing public understanding of science. Second, in shaping the activities capable of sparking it (Gross, 1994). Without rhetoric, the state lacks the "only means its citizens had for making common sense of a common past and for creating and coming to terms with a common future" (ibid, p. 5). I argue that, when combined with Bandelli (2015) contention that science communication should play a central role in ensuring reflexivity and self-criticism in science, this role of rhetoric in science aligns with

the contemporary push for anticipatory governance and a potential convening role for hype in science.

This role for science communication connects to the activism-aligned reading of public relations history and research outlined in Chapter 2. Here, public relations allowed activists in the early twentieth century to attempt to create social reform. These tactics today can be used to provoke, contest, and create social change (Coombs & Holladay, 2012). For these exercises to be participative and productive, publics in these debates must possess a meaningful ability to comment on benefits and risks, ownership and regulation (Nisbet & Scheufele, 2009; Stilgoe & Guston, 2017) (Brown, 2014). In public relations, this is achieved by empathising agency and by re-framing of the role of individuals participating in public debate as active, informed citizens who are joining discussions that affect their daily lives (Russell & Lamme, 2016; Taylor & Kent, 2014). In this frame, individuals and communities can co-create and negotiate identity, interest, and socially relevant meaning (Heath, 2014; Mead, 1934; Nichols, 1963). This brings us back to the emergence model in enabling opening and (ideally) critical discussion between science and citizens (Horst, 2013; Irwin, 2001). Helpfully, Raman et al. (2018) provide principles for science-society engagement in the public interest that are relevant here. These principles state that engagement: cannot be the same as endorsement; can generate learning by different parties; can open up alternative pathways for research and innovation; may involve the use of science to open up alternative policy pathways; and can help revivify what is understood to be in the public interest (p. 236 – 237). Here, engagement in the naming of public interest is not a consensus building exercise, but is, instead, a chance to build understandings of what research and innovation is desired, necessary, and relevant to the publics at hand.

How do the publics for these public discussions form? In a discussion of the Dewey-Lippmann debate on democracy and the role of informed citizens, Barnett (2008) and Marres (2005) argue that issues call publics into being when other actors make a claim to speak on their behalf. These publics cannot exist until they are spoken for and choose to pay attention and respond. Most significantly the potential of a new role for hype in science, Barnett stresses that the convening of publics is risky and hazardous because it "only works by risking the chance of misfires and infelicitous outcomes" (2008, p. 23). It is precisely this hazardous quality that I highlighted in Chapter 1 in discussion of Michael's 'the idiot' (Michael, 2012, 2013) and in Chapter 2 while discussing the contribution that public

relations makes to science communication. Here, rhetoric or persuasive communication invites the contribution of different perspectives and the establishment of other publics and allows science and technology actors to learn from responses made (Nisbet & Scheufele, 2009). Here, hype is the invitation that opens up a dialogue for response, new framings, and the contribution of additional knowledges to the design and re-design of science and technology futures.

Grand challenges represent a chance to revisit both the promise of anticipatory governance approaches and technology and this proposition for a new role for hype. As my findings from the case study in Chapter 5 demonstrate, current examples of grand challenges for research make muddled work of engaging citizens while still making claims to solve the issues that worry them daily. Horizon 2020, for example, was the grand challenge program that simultaneously made the most expansive claims for societal impact while being unable to provide evidence for those claims. The intention of involving civic actors and incorporating their responses to science and technology developments was expressed most coherently through the employment of a cross-cutting Responsible Research and Innovation framework for the program's seven societal challenges. However, reporting by the European Commission on the outcomes of this framework was limited and primarily concerned with necessary improvements before the end of Horizon 2020's seven years of funding. In this case, the hype or rhetoric of societal impact through the grand challenge-based approach seemed ill-justified. However, information from the Grand Challenges Canada and UCLA Grand Challenges program indicates not all is lost for the concept. Through Grand Challenge Canada's core concept of *Integrated Innovation* social innovation is placed on par with business, scientific and technological innovation. Meanwhile in the Sustainable LA Grand Challenge, documents produced by UCLA and the Office of the Los Angeles Mayor indicate that some concrete engagement is occurring through use of research outcomes and driving sustainability through community partnerships.

Grand challenges create a space in which citizens should be engaged or are already inherently engaged. The evidence for this engagement is sparse and varies between various examples of these programs. Perhaps it is this failure of hype – and by this, I mean a failure to follow through on the intent expressed through rhetoric for participation with these research agendas and projects – that might mobilise responses from "wider, more diverse, and otherwise inattentive publics" (Nisbet & Scheufele, 2009, p. 1770). Geels and Smith

point out that policy makers should not simply go along with promises for future impacts for the very reason that "many future images do not come true, because they are based on too simplistic conceptualisations of technological developments and [their] impact on society" (2000, p. 882). Here, publics can choose to respond to representations made on their behalf regarding the problems that worry them daily. More broadly and in terms of a role for hype in convening publics, I argue that engagement with the anticipatory practice that shapes these research agendas helps "to raise awareness about the types of futures mankind (sic) may encounter and sensitize society to the consequences of choices and actions of individuals and societies" (Boyd et al., 2015, p. S149). Instead of calling primarily for methods that mitigate prospects of disappointment by stopping hype (Apreda et al., 2014), the use of hype itself would invite response, agreeable and otherwise.

Limitations of the thesis

My research in this thesis has examined the use of hype in science and considered the other potential uses hype might be put to within a framework of anticipatory governance. Due to the design of this work, this thesis was not designed to vilify use of hype or to assess the validity of hyped-up claims. In addition, and unlike Sumner et al. (2016) and Caulfield (2005), I was not concerned with the exact source of exaggeration or whether that exaggeration was justified. My sole focus was exploring hype in science to establish a stronger theoretical understanding of its role in the production of expectations and visions for science and technology. The limitations of my thesis, as detailed below, represent opportunities for future investigation of hype in science. They include a call for additional and more diverse case studies and chart a path towards considering the implications of hype for trust and engagement.

Case studies are inherently limiting as generalisations cannot be made from them. An additional limitation of the case studies examined in my thesis is their geographical representation. My case studies were English, western, and liberal-democratic as they were drawn from the United Kingdom, Canada, the United States, and Europe. It is possible that my findings and conclusions are applicable to other countries and instances of hype. For instance, the European Union's Quantum Flagship and the German National Quantum Initiative share many characteristics identified in Chapter 4. However, it is impossible to say for certain.

Another limitation of the case studies is the disciplines or fields of research covered. In Chapter 3, I selected NASA for their long history of engagement with public relations and popular culture, Chapter 4 used quantum technology for its relative currency, and Chapter 5 focused on grand challenges as a sample of hype initiated by governments and funders rather than researchers and research institutions. This selection meant that I neglected hype in the biomedical and health sciences, in chemistry and archaeology, to name a few. Further investigation into case studies from these disciplines might reveal additional details as to how sociotechnical imaginaries are crafted and maintained through hype.

Finally, and as I outlined in Chapter 1, it was out of scope for this thesis to address trust and engagement in the context of science hype. First, I needed to address the research gap of what was missing in terms of how science communication research characterises and frames hype. With the foundation of this thesis, it should now be possible to investigate how hype affects different publics ability to trust in and engage with science and technology and to produce that necessary data on how hype affects different relationships with science (Master & Resnik, 2011; Nerlich, 2013).

In summary, this thesis investigated the role of hype in science. The research presented in the previous chapters brings together three bodies of literature to provide a framework for research into three examples of science and technology actors using hype to foster expectations and design select futures. The limitations outlined above provide new research directions to test and build on the conclusions of this thesis in order to form a broader view of the current and future role of hype in science.

Concluding remarks: Implications for science communication

This thesis has ultimately presented a story about the production of hype, how hype is crafted, and to what ends. In contrast to much of the current research into hype in science, the case studies I interrogated here present examples of hype on the macroscale. This meant that instead of focusing on individual cases of hype in science – such as the leapin' lesbian lizards tale I presented at the very beginning of my introduction chapter – I addressed hype in the long-term by focusing on the creation and subsequent evolution of expectations and visions for human space exploration, quantum enabled-technologies, and grand challenges for research. Further research might look further at the effect of this hype in terms of how it influences (or does not influence!) other publics. This research could

reflect on how the nature of competitive research funding requires hype and explore how the use of different communication channels impacts on the way hype manifests. It might also, as outlined in the limitations section above, look to hype's short- and long-term impacts, particularly in terms of trust and engagement with science and technology.

For hype to be a force for good, I believe that actors (scientists, science communication practitioners and researchers, and others) engaging in hype need to be reflexive and prepared for dialogue with their publics. The hybrid science communication role may be of assistance here. Hybrid science communicators – like myself – conduct a combination of research and practice. My role has embedded me amongst quantum physics researchers for more than four years. This has provided the opportunity of not just witnessing and analysing events, but actively working to shape them. In relation to anticipatory governance, increasing reflexivity, and engaging in dialogue, this kind of role presents an opportunity to both change default practices in the communication ecosystem of science and technology and to interrogate the effectiveness of those changes.

The examples of macro-level hype considered within this thesis showed how science and technology narratives become integrated into the sociotechnical imaginaries of organisations, nation-states, and transnational bodies. Hype speaks to the underlying work of imagination in science and technology. Not just in the sense of how researchers envision new developments in a lab or in the way engineers determine how research translates to a prototype, but also in the imagining of how new developments fit into the world and in how the world might need to change to incorporate them. In the spirit of my argument for the use of hype to convene publics, this thesis represents an invitation to readers who may concur (or not) with the views and research reported here to convene a conversation around hype and the role of performative expectations and futures in science and technology.

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Appendices

Appendix A: Participant information form

Participant Information Sheet

Researcher: My name is Tara Roberson. I am a PhD candidate at the ANU's Centre for Public Awareness of Science.

Project Title: National strategies for quantum technologies

General Outline of the Project:

- Description and Methodology: Interest and investment in quantum-based technologies has been consistently accompanied, or perhaps inspired by, hype: future-focused and often sensational rhetoric, centres on promises of technological application and economic gain. I am conducting research on how hype has been used in the establishment of national strategies for quantum science as part of my broader thesis which asks whether hype can be a force for good.
- Participants: I intend to interview 10 people who have been involved in the establishment of national strategies for quantum science in the UK, USA, and Canada. Interviewees will be recruited by email requests.
- Use of Data and Feedback: The data will be used to produce my thesis in addition to possible published articles and conference presentations. A summary of the research will be made available to participants via email.

Participant Involvement:
Voluntary Participation & Withdrawal: Participation in this research is voluntary and you may decline to take part or withdraw from the research without providing an explanation at any time until the work is prepared for publication. Within the research, you may decline to answer any question. If you withdraw, the data you have provided prior to withdrawal will be destroyed and not used.

What does participation in the research entail? You are invited to take part in an interview with me about your experiences of establishing a national strategy or agenda for quantum science. With your consent, I will record the interview so that I can accurately transcribe it, and the recordings will be destroyed after transcription.

Location and Duration: Interviews are expected to last for 30-45 minutes and will be conducted via a method of your choosing – for example, by video conference, phone call, or in person.

Risks: This research carries little risk, though there is a risk that despite my efforts to keep your identity confidential, you may be identified through the information that you tell me. You should not tell me anything that would incriminate you or cause others to take an unfavourable view of you.

Benefits: It is unlikely that you will personally benefit from participation in this research. I expect that this research will improve understanding of the ways hype can be used to highlight issues for policy initiatives.

Exclusion criteria:
Participant Limitation: This study is only concerned with people who have direct experience in advising on and advocating for national strategies for quantum science.

Confidentiality:
Confidentiality: I will keep your identity confidential as far as allowed by law, unless you elect to be named within the research. Access to the data you provide will be restricted to me and identifying details will be stored separately through the rest of the research data. You will not be identifiable within published outputs unless you have elected otherwise.

Privacy Notice:
In collecting your personal information within this research, the ANU must comply with the Privacy Act 1988. The ANU Privacy Policy is available at https://policies.anu.edu.au/ppl/document/ANUP_010007 and it contains information about how a person can:

- Access or seek correction to their personal information;
- Complain about a breach of an Australian Privacy Principle by ANU, and how ANU will handle the complaint.

Data Storage:

- Where: Data will be stored on a password protected and encryption hard drive. Physical records will be kept in a locked filing cabinet in my office at the University of Queensland.
- How long: All research data will be retained and securely stored for at least five years following publications from the research.
- Handling of Data following the required storage period: After the storage period, all identifying details will be removed from the data and non-identified data will be archived at the Australia Data Archive (www.ada.edu.au). If the data contains privileged or confidential information, it will be destroyed.

Queries and Concerns:
Contact Details for More Information: Any requests for information or queries regarding the study can be directed to tara.roberson@anu.edu.au (61 404 516 635) or my supervisor Professor Joan Leach (joan.leach@anu.edu.au)

Ethics Committee Clearance:
The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee (Protocol 2018/703). If you have any concerns or complaints about how this research has been conducted, please contact:

Ethics Manager
The ANU Human Research Ethics Committee
The Australian National University
Telephone: +61 2 6125 3427
Email: Human.Ethics.Officer@anu.edu.au

Appendix B: Participant consent forms (written consent and oral consent)

WRITTEN CONSENT for Participants

National strategies for quantum technologies

I have read and understood the Information Sheet you have given me about the research project, and I have had any questions and concerns about the project (listed here

_____

_____)

addressed to my satisfaction.

I agree to participate in the project. YES ☐ NO ☐

I agree to this interview being audio-recorded YES ☐ NO ☐

I agree to be identified in the following way within research outputs:

Full name YES ☐ NO ☐

Pseudonym YES ☐ NO ☐

No attribution YES ☐ NO ☐

Signature:…….

Date:…….

ORAL CONSENT SCRIPT for Participants

National strategies for quantum technologies

I have read to you the Information Sheet about the research project. Was this information clear? Do you have any questions about the project?

Do you agree to participate in this project?

Do you agree for this interview to be audio-recorded?

When I prepare the research outputs, I can attribute information to you in three ways: full name, pseudonym, or I can use NO attribution and hold your information confidentially.

- Would you like information attributed using your full name?
- Would you like to be referred to using a pseudonym (false name)?
- Would you prefer that your information be not attributed to anyone at all?

May we start the interview now?

Record the date of this script being read